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RAGWORT.

From an original painting by Sir Harry Johnston, G.C.M.G.

THE . .

LIVING PLANT

IN LEAF, FLOWER, AND FRUIT

A POPULAR BOOK ON BOTANY
FOR THE GENERAL READER

BY

ALFRED ERNEST KNIGHT

AUTHOR OF "A MONOGRAPH ON THE BRITISH SPECIES OF LABIATÆ,"
"LUMINOUS PLANTS," ETC.

AND

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AUTHOR OF "THE ROMANCE OF WILD-FLOWERS," "WAYSIDE
AND WOODLAND BLOSSOMS," ETC.

WITH

871 ILLUSTRATIONS

SPECIALLY DRAWN FOR THE WORK BY A. E. KNIGHT
AND 36 PLATES PRODUCED DIRECT FROM PHOTOGRAPHS
AND A COLOURED PLATE FROM AN ORIGINAL
PAINTING BY SIR HARRY JOHNSTON, G.C.M.G.

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PREFACE

THE present volume is an attempt to simplify the study of Botany for general readers.

Our starting-point is the supposition that the student knows really nothing of the conditions of Plant Life, yet that he desires to be put upon the way of obtaining something more than a superficial Peter Parley acquaintance therewith. It has been supposed, indeed, that he is ambitious of acquiring such a grasp of the leading principles of the science as shall enable him to read with interest the more advanced treatises on the subject, as well as to engage in practical work on his own account. Hence the difficulties of the study have not been slurred over, as is so often done in works intended to be popular. We have rather sought *to lead the student through those difficulties*, anxious only that this shall be done in a simple and entertaining manner. When the wood becomes intricate, we have not turned aside, but by means of illustration and experiment have pointed out an easy, and, as we trust, a pleasant path through the tangle.

So far as our knowledge goes—and we have taken some trouble to be well-informed—the public hitherto have been in possession of no work on the lines indicated. There are many able text-books of the skeleton type, and not a few books on Plant Life in which the difficulties of the subject have been industriously shelved, but we believe that this is the first attempt—at least, in a volume of reasonable bulk—to present the essentials of the science in a complete and popular manner. Whether the attempt has been successful is, of course, another matter, which must be left for readers of the book to determine.

And here we would indicate a few of the features which may be thought to lend the attraction of novelty to the work. In the opening chapter, the mysterious principle of Life—most impressive of all subjects—has been dealt with far more expansively than is the rule in works of this class; while

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the closely related phenomena of cell formation and transformation, which are usually crowded into two or three pages, or perhaps ignored altogether, have had two chapters devoted to them. These, we think, are new features; and we claim that the great importance and absorbing interest of the subjects justify a pretty wide departure from established methods.

Then there is the Leaf. The facts connected with the anatomy and physiology of leaves lend themselves readily enough to popular treatment; but the task of imparting interest to so barren a theme as the *shapes* of leaves is, it must be confessed, no easy one. Nevertheless, this difficulty has been partially—may we trust, *entirely*?—surmounted by the plan which has been adopted in the chapter devoted to that topic. It consists—and this is the novel feature—in describing for the reader an imaginary ramble by hedgerows and winding stream, through meadows and cornfields, which are made to render up in succession the leaf-forms required. The essential facts connected with this part of the study are doled out at intervals, under cover of a chatty disquisition on the wild-flowers gathered by the way; and thus a tedious terminology, with its corollary of definitions, may be received into the memory without effort, like a James's powder strategically concealed in jam.

In other sections of the work, and particularly in Chapters X. to XIII., there is a similar departure from conventional methods. The morphology of flowers and fruits, as treated in works on general Botany, is far from interesting to the general reader; but here the subject has been fully considered in the light of adaptation, which invests it with the charm of romance. For that purpose we have sedulously availed ourselves of the discoveries of the great specialists in this department—Darwin, Delpino, Hildebrand, the two Müllers, Behrens, Bennett, Kerner von Marilaun, and others; and by approaching the subject on the lines indicated, have been enabled to direct frequent attention to the part which animals, wind, and water play as pollinators and seed distributors; as well as to point out the links which subsist between those agents and the elaborate mechanical contrivances, strange forms, and multifarious subsidiary appendages of floral organs and seed-vessels.

It will be seen that we have been sparing of quotations, and particularly of poetical quotations; nevertheless, we have had regard to the fact that the work is of a popular character, and have not excluded such attractive helps altogether. Knowing what has been said about "purple patches," and cordially admitting the evil of much that has been objected to, it still appears to us that a work is not *necessarily* disfigured by quotations. Where the extract is plainly suggested by the context, not merely dragged in for rhetorical display, it is surely admissible.

Facts derived at first hand from well-known books of travel have sometimes been given in the writer's own words; but for this no apology is needed, as descriptions of plants in their native habitats, if penned on the spot, have a vividness of realism which is easily lost in the process of literary recasting and touching up. We say "at first hand," in contrast with facts gleaned from formal treatises on Botany, which are seldom the fruit of personal investigation on the part of the writers,* and in most cases are dealt with in too learned a manner to be available as quotations.

It may be added that, with one or two exceptions, the whole of the original matter contained in the volume appears in print for the first time; the chief exception embracing the remarks on luminous plants in Chapter V., which formed the substance of a paper by Mr. Knight in *The Pall Mall Magazine.* His share in the work, besides the drawings, consists of Chapters I. to XIII. inclusive, and the Introduction, while Mr. Step is responsible for the concluding chapter.

Special care has been given to the illustrations, of which there is a liberal supply. The diagrams relating to æstivation are copied from the conventional figures of the text-books, which are common property; while the drawings of *Blastophaga grossorum,* the insect pollinator of the Common Fig, have been sketched from steel engravings in the rare Italian work, *Ricerche sulla Natura del Caprifico, a del Fico; e sulla caprificazione.* The rest of the illustrations (nearly seven hundred in number) are original. To the many friends who have assisted in this department, by supplying rare flowers from their conservatories and cabinets, or with microscopical slides, our warmest thanks are due. But for them many subjects must have been left unillustrated, particularly in that part of the work where it was most desirable that illustrations should appear—viz., the chapters on Fertilisation.

It is needless to weary the reader with the long list of works to which we are under obligations; and to specify certain books as having been of more service than others would be a thankless and invidious task. The titles of most of them will be found at the end of the volume, and not a few of the authors' names are contained in the text.

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* This remark does not, of course, apply to the larger works on plant structure and functions such as Sachs's celebrated *Lehrbuch,* or to those on special departments of physiology, like Müller's *Die Befruchtung der Blumen durch Insekten* and Darwin's laborious productions.

Of distinguished botanists to whom we are more personally beholden, special mention must be made of the Cambridge Reader in Botany, Mr. Francis Darwin, F.R.S., for his courtesy in indicating out-of-the-way sources of information on the subject of fertilisation; of the veteran local botanist, Mr. Leo Grindon, for the loan of valuable prints and specimens from his fine collection at Manchester; and of the able ex-Curator of the Royal Gardens at Kew, Mr. George Nicholson, F.L.S., for information upon many points in which his exceptional knowledge was of peculiar value. We must also acknowledge our indebtedness to Mr. W. Watson, Curator of the Gardens; to Mr. Henry Burkill, late of the Royal Herbarium at Kew; to the respected member of the Entomological Department of the British Museum, Mr. W. F. Kirby, F.L.S.; and, lastly, to Professor Lionel Beale, F.R.S., the eminent biologist and sometime President of the Royal Microscopical Society, whose invaluable works on protoplasm have long enjoyed a European reputation. His letters to one of us, full of encouragement and admirable counsel, and his help in other ways, will ever be gratefully remembered.

In conclusion, we would express a hope that the book will be found to offer profitable entertainment to the large class to whom it is primarily addressed, and that those who are taking up the study of Botany for more special ends will find it sufficiently full and reliable, nor think its usefulness diminished because the drier details of the science have been dealt with in a popular manner.

A. E. K.
E. S.

CONTENTS

PAGE
PREFACE iii
INTRODUCTION 1
CHAPTER I. THE PROTOPLAST 5
" II. THE PROTOPLAST AS HOUSE-BUILDER . . . 20
" III. CELL COMMUNITIES: A CHAPTER ON TISSUES . . 47
" IV. THE ASCENDING SAP 57
" V. THE DESCENDING SAP 78
" VI. SEED AND ROOT 107
" VII. NATURE'S WOODCRAFT: A CHAPTER ON STEMS . . 141
" VIII. LEAF-BEGINNINGS AND LEAF-FORMS 169
" IX. THE LEAF IN RELATION TO ITS ENVIRONMENT . 200
" X. FLORAL FORMS AND THEIR RELATIONS TO INSECTS . 228
" XI. THE WELCOME OF THE FLOWERS 277
" XII. SOME PLANT MARRIAGES 321
" XIII. THE PROMISE OF THE PLANT THAT IS TO BE . . 348
" XIV. HIDDEN MARRIAGES 377
GLOSSARY OF TERMS 406
LIST OF AUTHORITIES 409
INDEX 411

LIST OF PLATES

To face page

Frontispiece. RAGWORT. *From an original painting by* SIR HARRY JOHNSTON, G.C.M.G.
Plate I. THE CLOCK-PLANT (*Desmodium Gyrans*) 216
„ II. "PRIMROSES BY THE RIVER'S BRIM" 2
„ III. WILLOW-LEAVED SPIRÆA (*Spiræa salicifolia*) 92
„ IV. "THE MARSHY SEDGY SHALLOWS". 3
„ V. A PITCHER-PLANT 75
„ VI. 1. BACILLUS (*Kitasato*) OF BUBONIC PLAGUE, WITH FLAGELLA .
2. COMMON BACILLUS (*Spirochæte choleræ asiaticæ*) OF ASIATIC CHOLERA, WITH FLAGELLA . . . .
3. A SPECK OF PROTOPLASM AS SEEN UNDER THE MICROSCOPE . .
4. MICROSCOPIC VIEW OF BEADED HAIRS OF *Tradescantia virginica*, SHOWING ROTATION OF PROTOPLASM 15
„ VII. MAGNOLIA (*M. glauca*) 228
„ VIII. YUCCA-PLANT (*Y. gloriosa*) 333
„ IX. ONE OF THE COTTON THISTLES (*Onopordon bracteatum*) 177
„ X. BULBOUS BUTTERCUP (*Ranunculus bulbosus*), POPULARLY KNOWN AS CUCKOO-BUDS 126
„ XI. GALLS OF *Dryoteras terminalis* (OAK APPLE) 223
„ XII. WILD GINGER (*Asarum canadense*), WITH RENIFORM LEAVES . . . 187
„ XIII. HARE'S-FOOT CLOVER (*Trifolium arvense*) 184
„ XIV. WALKING FERN (*Camptosorus rhizophyllus*—ALSO CALLED *Scolopendrium rhizophyllus*) WITH ROOTING FRONDS 174
„ XV. FRUITING BRANCH OF THE GRAPE VINE (*Vitis vinifera*), WITH LOBED AND SINUATE-TOOTHED LEAVES 183
„ XVI. MALE AND FEMALE CATKINS OF THE ALDER (*Alnus glutinosa*) . . 344
„ XVII. SPEAR THISTLE (*Cnicus lanceolatus*) 321
„ XVIII. *Clematis Jackmanni* 242
„ XIX. *Alocasia spectabilis* 204
„ XX. SNOWDROP (*Galanthus nivalis*) WITH PENDULOUS FLOWERS . . . 278
„ XXI. WHEAT (*Triticum vulgare*) 115
„ XXII. SKUNK CABBAGE (*Symplocarpus fœtidus*) 231
„ XXIII. FLAMINGO-PLANT (*Anthurium Scherzerianum*) 302
„ XXIV. *Brunsvigia Josephinæ* 147
„ XXV. TWO WELL-KNOWN LAWN AND SHRUBBERY TREES 218
„ XXVI. YELLOW PLUMS, FRUIT OF AN AMERICAN SPECIES OF PLUM-TREE (*Prunus Americana*) 367
„ XXVII. YUCCA-PLANT (*Yucca gloriosa*) 334
„ XXVIII. PEAR-TREE (*Pyrus communis*) LADEN WITH BLOSSOM 264
„ XXIX. AFRICAN LILY (*Agapanthus umbellatus*) 235
„ XXX. FRUITING BRANCH OF CLARET VINE (A FORM OF *Vitis vinifera*) . . 368
„ XXXI. A SPECIES OF *Phyllocactus* FROM CENTRAL AMERICA 220
„ XXXII. *Horminum pyrenaicum* 277
„ XXXIII. DOUBLE POPPIES, VARIETIES OF *Papaver somniferum* 228
„ XXXIV. COMMON HYDRANGEA (*H. hortensis*) 240
„ XXXV. MOREL (*Morchella esculenta*) 395
„ XXXVI. DENSELY FLOWERED CORYMBS OF A WHITE, SWEET-SCENTED SPECIES OF CLEMATIS 321

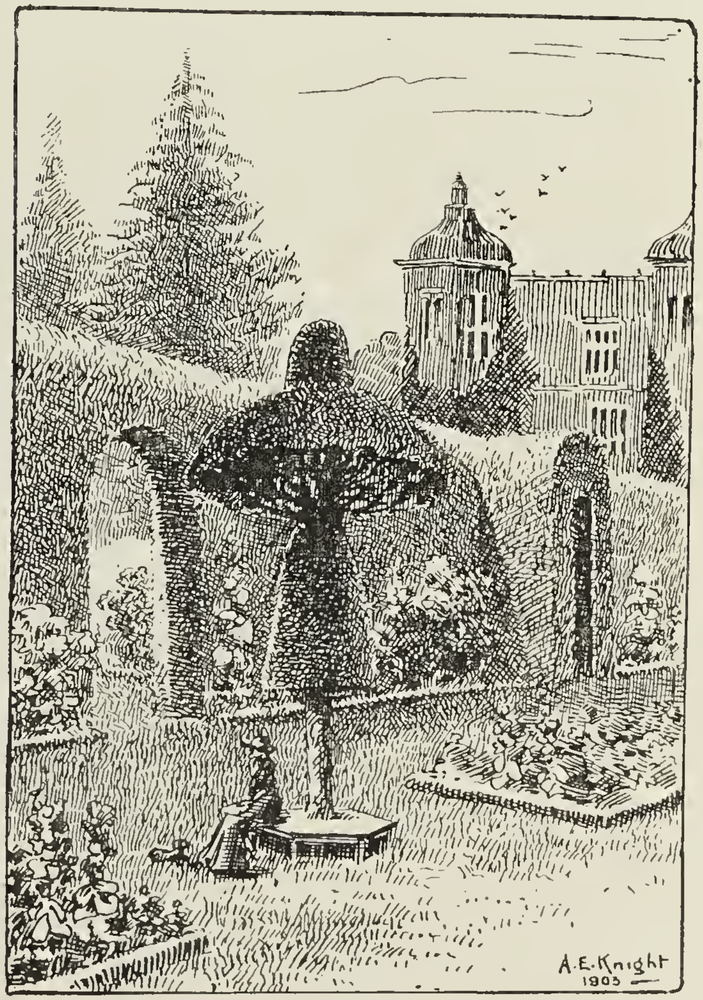
THE LIVING PLANT: IN LEAF, FLOWER, AND FRUIT

INTRODUCTION

And hark! how blithe the throstle sings!
He, too, is no mean preacher:
Come forth into the light of things,
Let Nature be your teacher.

She has a world of ready wealth,
Our minds and hearts to bless,—
Spontaneous wisdom breathed by health,
Truth breathed by cheerfulness.
WORDSWORTH.

OUR delightful poet Cowley, in one of the choicest of his essays, tells of the desire he always had to be "master of a small house and garden, with very moderate conveniences joined to them," in order that he might dedicate the remainder of his life "only to the culture of them and the study of Nature."

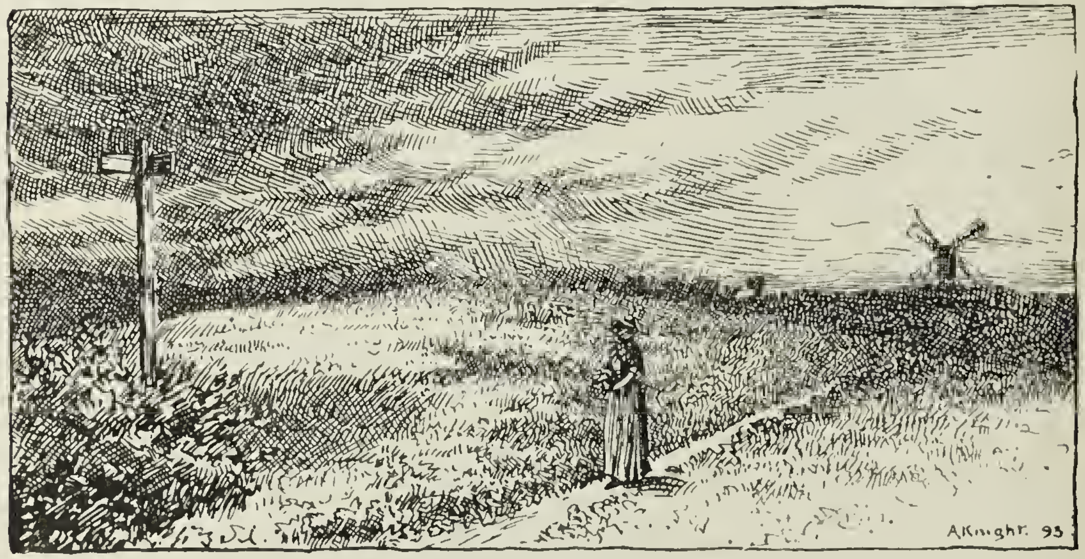


An old English garden.

We can all understand this satisfaction and delight in Nature; yet many, perhaps, while confessing to a sincere admiration for all that is beautiful, would shrink from the study of Botany, and look upon it, maybe, as a dull science, occupied only with desiccations and dissections, and the endless acquisition of names. To such persons a botanist is a dry-as-dust gentleman, after the pattern of the meagre philomath in Miss Kendall's *Dreams to Sell*, who saw in Nature a soulless something, without beauty and without sentiment:—

> He loved peculiar plants and rare;
> For any plant he did not care
> That he had seen before:
> Primroses by the river's brim
> Dicotyledons were to him,
> And they were nothing more.

Professor Dawson is, we believe, responsible for the saying: "I hate Theology and Botany, but I love religion and flowers"; and if by the term Botany the professor meant only those dry-as-dust expositions of the science which some of us know so well, then we are quite at one with him. But it would seem that the professor's antipathy is to the science itself, as opposed to the more æsthetic study of Nature; and here his laconicism may prove misleading. "You study Nature in the house" (*i.e.*, in dried specimens), wrote Professor Agassiz, "and when you go out of doors you cannot find her"—suggestive words, that unlock the secret of many a wearying failure.



The bald burnt moor.

Dr. Lindley well observes on this point: "Only to apply their names to a few plants is a poor insipid study, scarcely worth the following; but to know the hidden structure of such curious objects, to be acquainted with the singular manner in which the various actions of their lives are performed, and to learn by what certain signs their relationship—for they have their relations like ourselves—is indicated, is surely among the most rational and pleasing of pursuits." Depend upon it, therefore,

From a drawing by A. E. Knight.

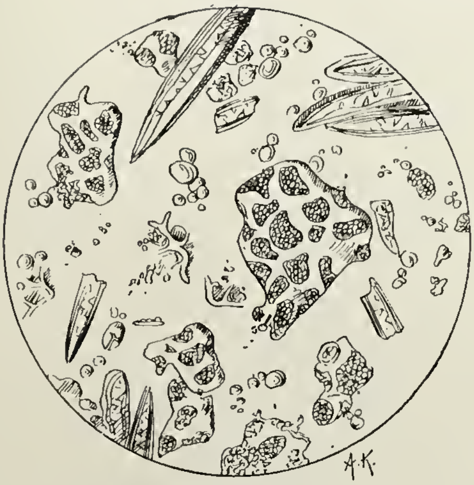
"PRIMROSES BY THE RIVER'S BRIM."

PLATE II.

From a drawing by A. E. Knight.

PLATE IV.

"THE MARSHY SEDGY SHALLOWS."



Pure Coffee as seen under the microscope.

if the study of Botany has become to any one a dead letter instead of a living word, it is because it has been pursued apart from Nature, and hence the great purpose of the science has never been truly grasped.

Now to an author it is, of course, impossible to take his readers out of doors; but we trust that long before the last page of this work has been reached we shall have fulfilled the humbler task of awakening an interest in the subject that shall compel the reader to go forth and make that closer acquaintance for himself, for there is nothing in Nature, however humble or apparently insignificant, which is not deserving of patient and whole-hearted study, or which will fail to reward the serious student.

The wilderness of thorns and brambles
Beneath whose weeds the muddy runnel scrambles;
The bald burnt moor; the marshy sedgy shallows,
Where docks, bulrushes, water-flags, and mallows
Choke the rank waste, alike can yield delight;
A blade of silver hair-grass nodding slowly
In the soft wind; the thistle's purple crown;
The ferns, the rushes tall, and mosses lowly;
A thorn, a weed, an insect, or a stone—

yes, even the green slime upon a stagnant pool and the mildew on a damp wall are replete with interest; and in the reverent study of these simple objects is to be found instruction of the highest kind.

It may be added that the study of Botany has special advantages over almost all other sciences, inasmuch as it is concerned with objects which are found in every region of the globe. It is a study which relieves the monotony of town life, and adds interest to every walk in the country. It proposes nothing that could cause distress to a sensitive mind. It quickens the observing powers of the mind; and habits of accuracy and

Adulterated Coffee as seen under the microscope.

caution, so needful in every walk of life, grow out of the practice of putting Nature to the question. Best of all, no one is excluded from the study. It may be taken up by either sex, at any and every period of life; and the poor are as free to pursue the study as the rich.

Nor must the great practical importance of a knowledge of plants be overlooked. The use of vegetable products to man, and to the animal creation generally, is sufficiently obvious. All life would quickly disappear from the earth if vegetable life were withdrawn. For instance: pure air is essential to animal life and vigour, and plants are great air purifiers. They feed upon the carbon dioxide given off by animals, taking in this food for the most part from the atmosphere; and they give off oxygen in great quantities, thus making up for that consumed by the animal kingdom.

One is tempted, too, to touch upon the fact that, had there been no microscopic researches into Nature, our eyes would probably never have been opened to the impositions practised upon us by fraudulent purveyors, whose skill in mixing granules of potato-starch with our flour and bread, canna-starch with our cocoa, chicory and roasted wheat with our coffee, foreign leaves and china-clay with our tea, and cabbage-leaves with our tobacco, is now so well known.

Thus the study of Botany presents illimitable possibilities to us — advantages hardly to be overstated. Its claims are, indeed, threefold—moral, intellectual, and economic. It might even be said that there is a religious suggestiveness in the study. Solomon "spake of trees, from the cedar-tree that is in Lebanon even unto the hyssop that springeth out of the wall"; and surely there is every warrant to approach the subject, and, with the great class-book of Nature open before us, to learn in "leaf, flower, and fruit" the lessons of the Plants.

The Cedar of Lebanon.

CHAPTER I

THE PROTOPLAST

Oh, for a glance into the earth!
To see below its dark foundations
Life's embryo seeds before their birth,
And Nature's silent operations.
GOETHE.

IT is perhaps superfluous to observe that no links have yet been found between living and not living, between organic and inorganic matter, and therefore between plants and minerals. The doctrine of *spontaneous generation*, by which it has been attempted to supply such a link, is based upon assumption and not ascertained facts. The most powerful plea that can be urged for the doctrine is its antiquity. The ancients had their theory of spontaneous generation; though the ancients were not always right. It was Aristotle's belief and teaching that frogs and snakes sprung from mud and slime; and readers of Virgil (*Georg. IV.* 330–65) will recollect the poet's recipe for raising a swarm of bees from the putrefying corpse of a two-year-old bullock, by strewing broken boughs and flowers of thyme and cassia under the corpse. We must confess that our faith in the philosopher's opinion, no less than in the virtue of the poet's recipe, is somewhat weak. Observation teaches that Life, which distinguishes the Mineral from the Vegetable and Animal Kingdoms, does not spring up spontaneously. The *principle* of Life must be there first, under whatever conditions; and hence it is safe to affirm that the doctrine of "Life from Life," or *biogenesis*, is the true doctrine. "Dead matter," said Lord Kelvin before the British Association some years ago, "cannot become living matter without coming under the influence of matter previously alive. This seems to me as sure a teaching

Fig. 1.—Leaf Butterfly.

of science as the law of gravitation. I am ready to adopt as an article of scientific faith, true through all space and through all time, that Life proceeds from Life and nothing but Life."

The German botanist Schleiden, taking the crystal as the type of the most perfect form of inorganic body, thus beautifully contrasts it with a living organism, the plant *Hordeum*, or Barley (see opposite page). "The crystal does not spring at once a perfect Minerva from the hand of Jupiter; the matter of which it is formed undergoes a constant series of changes, the final result of which is the completed shape of the crystal. The crystal, too, has an individual history, a biography, but only a history of its *becoming*, its origination. . . . Plants and animals form the most distinct contrasts to this, and herein lies that common nature, which induces us to comprehend them in one conception, as organic or living existence. . . . In spring we commit the barley-corn to its nurse, the earth; the germ begins to move, starts from its envelopes, which fall to decay. One leaf after another appears and unfolds itself; then the flowers display themselves in a thickly crowded spike. Called forth through wonderful metamorphoses, in each originates the germ of a new life; and while this with its envelopes becomes perfected into a seed, constant changes in the plant, from below upwards, are in progress. One leaf after another dies and withers. At last but the dry and naked straw-haulm stands there. Bowed down by the burden of the golden gift of Ceres, it breaks up and rots upon the earth, while within the scattered germ, lightly and snugly covered by protecting snow, a new period of development is preparing, which, beginning in the following spring, continues on the unceasing repetition of these processes. Here there is nothing firm, nothing consistent; an endless becoming and unfolding, and a continual death and destruction, side by side and intergrafted. Such is the Plant! It has a history, not

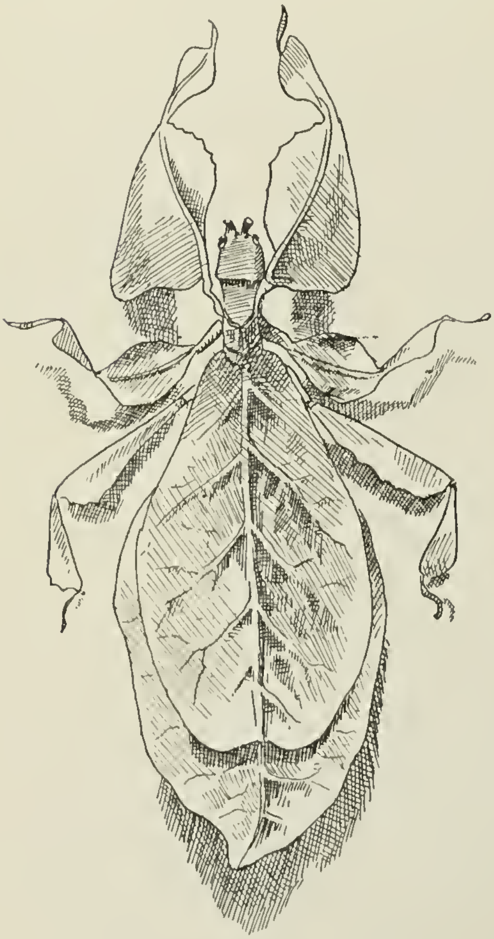
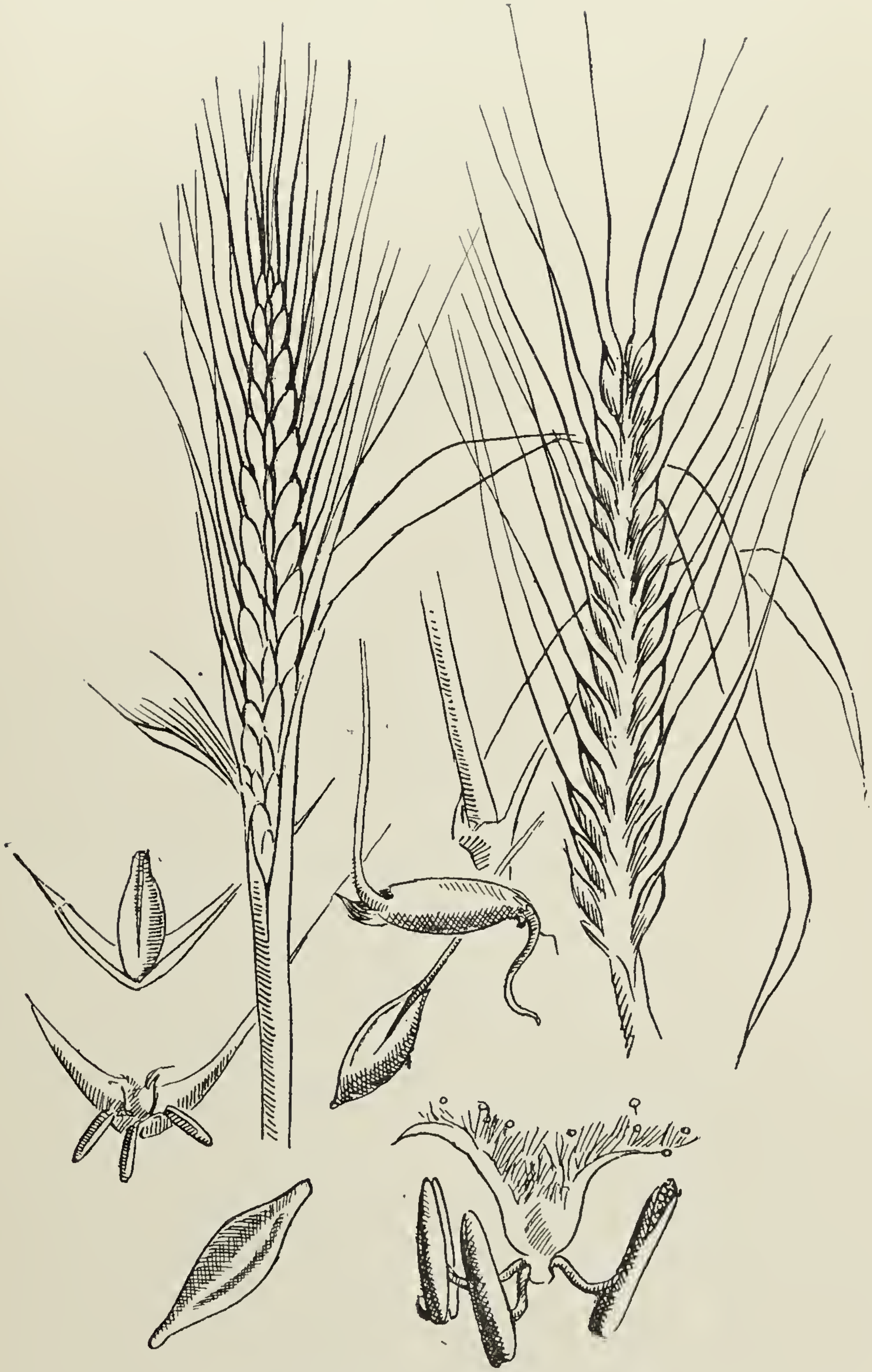


Fig. 2.—Walking-leaf Insect.



The Barley-plant: its life-history from seed to fruit.

The upper part of this illustration shows an unripe (the left-hand figure) and a ripe inflorescence. To the left of the former are two detached flowers (spikelets) with extended glumes. Below these is a barley-corn or ripe fruit, and immediately to the right of the barley-corn a representation of the male and female organs of a single flower. In the centre is shown a fruit in process of germination.

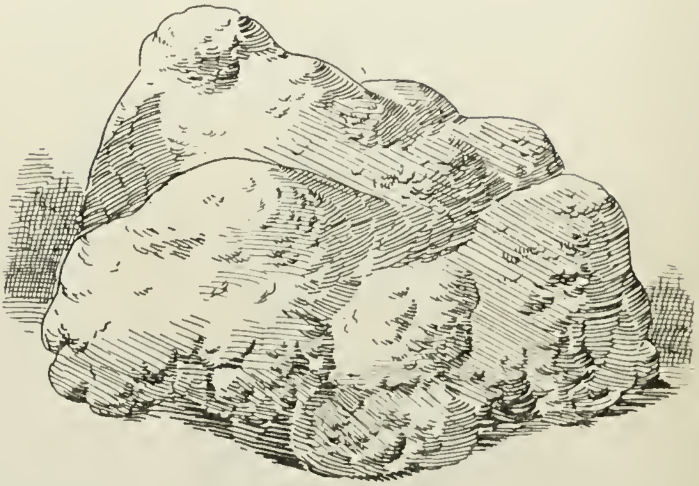


Fig. 3.—The Haastia of New Zealand: a plant which forms masses so closely resembling a sheep that it is often mistaken for that animal.

only of its *formation*, but also of its *existence*; not merely of its *origin*, but of its *persistence*. We speak of plants; where are they? When is a plant perfect, complete, so that we may snatch it out of the continual change of matter and form, and examine it as a thing *become*? We speak of shapes and forms: where shall we grasp them, disappearing Proteus-like every moment and transformed beneath our hands? . . . In every moment is the Plant the ruin of the past, and yet, at the same time, the potentially and actually developing germ of the future; still more, it also appears a perfect, complete, and finished product for the present" (*The Plant*).

Matter, indeed, is too coarse and low a thing to imprison life. Life uses up the virtue out of matter, and when for a space it looks as if the matter lived, it is only for a little time, and the Life passes on to use up fresh material. The former living plant or animal, as we saw it, decays away; but the Life has not decayed: it has changed its place, and has made a step in its mysterious and immeasurable cycle—always unseen, unmeasured, and untouched. How different from the inorganic crystal, which knows nothing of this ceaseless change and progression; which has no life history to offer; which, in fact, has never been alive!

Wide, then, is the chasm, and very definite the line of demarcation, between organic and inorganic bodies—between the Plant, which has Life, and the Mineral, which is lifeless. Biology, indeed, which is the science of life, concerns only the Animal and Vegetable Kingdoms—it has no connection with the Mineral world. Botany and Zoology, the sciences that deal respectively with plants and animals, are its two main subdivisions; and Mineralogy is of necessity excluded. Of course it is only with the first of these sub-divisions that we have to do: the subject before us is Botany, not Zoology. The word "Botany," we may remark in passing, is a Greek word, meaning any kind of grass or herb, and *botanikē*, in the same language, signifies the art which teaches the nature

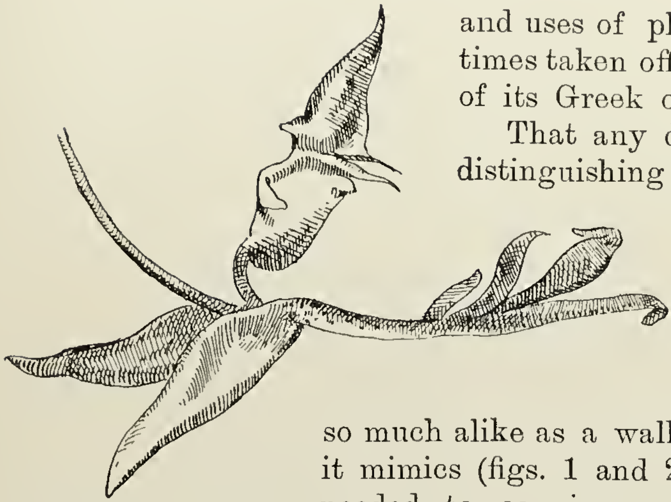


Fig. 4.—Punch-and-Judy Orchid.

and uses of plants. The dry look is sometimes taken off a subject when the meaning of its Greek or Latin name is explained.

That any difficulty should be found in distinguishing plants from animals might at first occasion some surprise. A cow is not mistaken for a cucumber, nor an oyster for a water-lily; and even when we take objects externally so much alike as a walking-leaf insect and the leaf it mimics (figs. 1 and 2), very little examination is needed to convince us how essentially different they are. Many persons have been deceived by the interesting Haastias and Raoulias of New Zealand (fig. 3), curious plants allied to *Gnaphalium*, which form masses on the bare mountain tops so closely resembling sheep at a very short distance, that the most experienced shepherds are often deceived by their appearance. Here also, however, the deception vanishes on a closer inspection; and the same thing may be said of many orchideous flowers, whose remarkable resemblances to objects in the sister kingdom have been often dwelt upon—as, for example, the Punch-and-Judy Orchid (fig. 4). Nevertheless, in other cases real difficulties of distinction exist; and to prepare a definition either of an animal or a plant, which shall be at once sufficiently full and sufficiently exclusive, is in the present state of our knowledge impossible. Probably, indeed, the line of demarcation between the two kingdoms will never be absolutely determined.

Three important characteristics, may, however, be said to distinguish the *higher* animals—viz., the power of locomotion, evident sensitiveness, and the possession of a special digestive cavity for receiving solid food; just as the absence of these characteristics will be found to distinguish the higher plants; though even here exceptions are

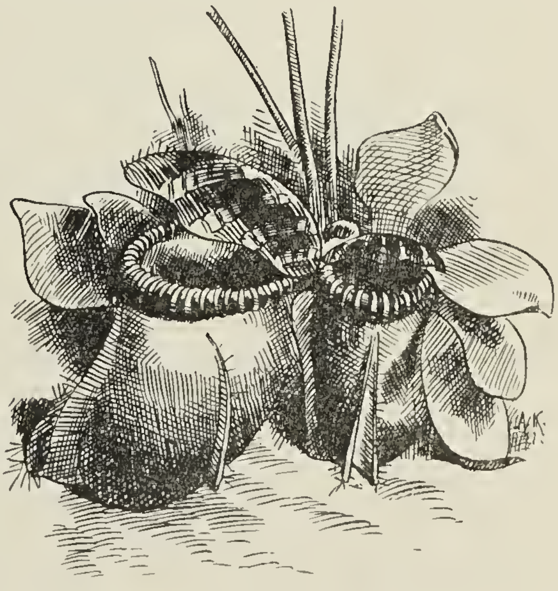


Fig. 5.—New Holland Pitcher-plant.

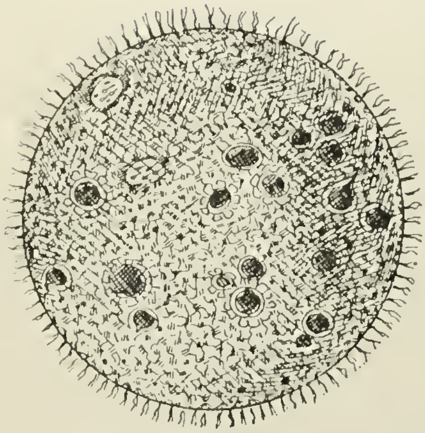


Fig. 6.—*Volvox globator.* By means of its delicate hairs or *cilia*, which work with harmonious action, this plant propels itself through the water.

not wanting. Thus, among the higher animals the oyster lacks the power of locomotion, and the tapeworm has neither sensitiveness nor a special digestive cavity; while among the higher plants we find a power of locomotion in the spermatozoids of Ferns, extreme sensitiveness in the Mimosas, and "a kind of external stomach which digests solid food'' in the Pitcher-plants (fig. 5). The proposal gravely made by a French savant to define an animal as *un estomac servi par des organes*, is, therefore, not to be thought of; and the inadequacy of the definition is more plainly seen when we descend to the lower forms of life. Here, not only are locomotion and apparent sensitiveness common among the simpler water-plants, as *Sphærella pluvialis** and *Volvox globator* (fig. 6), but the absence of a digestive cavity is the rule rather than the exception in the lower animalculæ, of which the *Amœba* and its immediate allies furnish good illustrations. Indeed, we must ascend the zoonic scale as high as *Vorticella*, the curious little Bell-animalcule (fig. 8), before we meet with even the rudiments of a digestive apparatus.

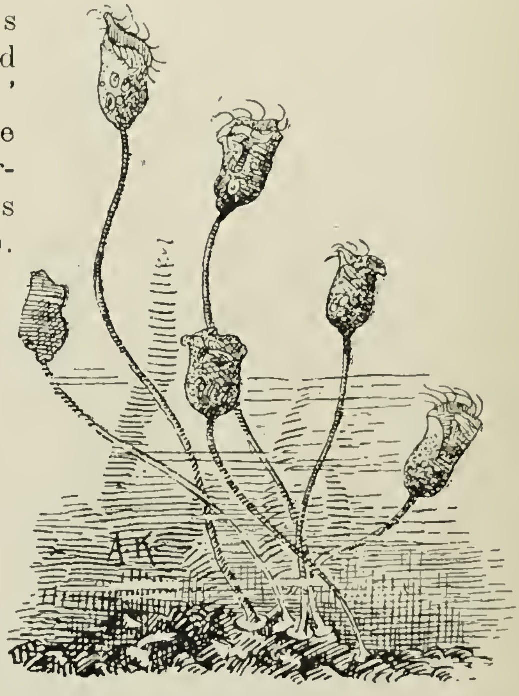


Fig. 8.—*Vorticellæ*: microscopic animals belonging to the group Infusoria.

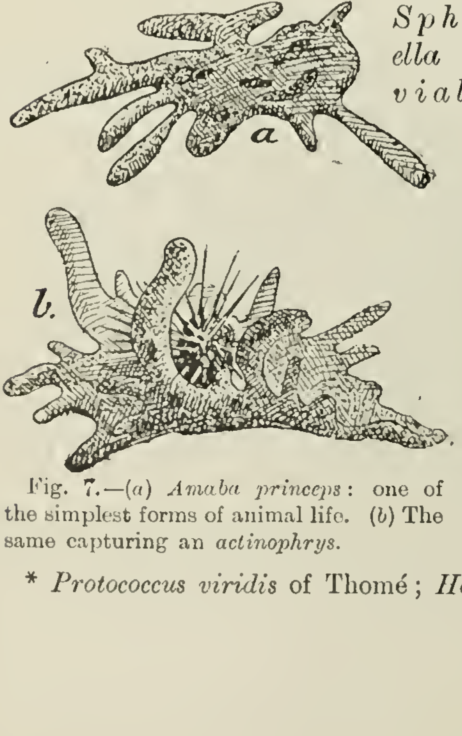


Fig. 7.—(*a*) *Amaba princeps*: one of the simplest forms of animal life. (*b*) The same capturing an *actinophrys*.

Now any one who would understand the complex forms of Life, whether

* *Protococcus viridis* of Thomé; *Hæmatococcus pluvialis* of Flotow, Prantl, and Vines.

in the Animal or Vegetable world, does well to begin low down in the scale, by studying Life in its simplest forms; and *unicellular*, or one-celled plants supply excellent examples for the purpose. Allusion was made a moment ago to *Sphærella pluvialis*, one of the simplest forms of vegetable life; a microscopic water-plant often to be met with in rain-water cisterns, or as green and reddish incrustations in damp places. *Sphærella* is an unicellular plant; and as we desire to speak a little of the life-history of a single cell, it may be well to take a nearer view of this tiny organism.

If you take some rain-water from a cistern into which the sun has been shining for a few hours, and examine a drop of it under the microscope, you will probably find that it is teeming with life. Minute pear-shaped bodies of a green colour swim rapidly about (fig. 9*a*), propelling themselves along by delicate filaments of a transparent substance, which branch out, two on each individual, from a tiny red spot (termed the *eye-spot*), which might at first be thought to be a head. The movement is due to the alternate shortening and lengthening of these filaments or *flagella*, which are so fine and transparent, and lash the water so rapidly as to be scarcely visible. By-and-by the movement becomes slower, and ceases; the flagella disappear; the green bodies, as though ashamed of swimming about in their nakedness so long, form little jackets for themselves of a substance hereafter to be described, and sink to the bottom of the water, where they enter upon a new stage of existence (fig. 9*b*).

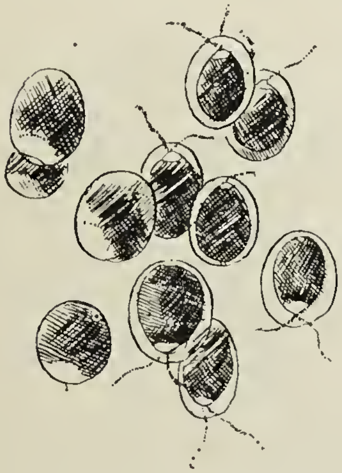


Fig. 9*a*.—Motile stage of zoospores of *Sphærella pluvialis*.

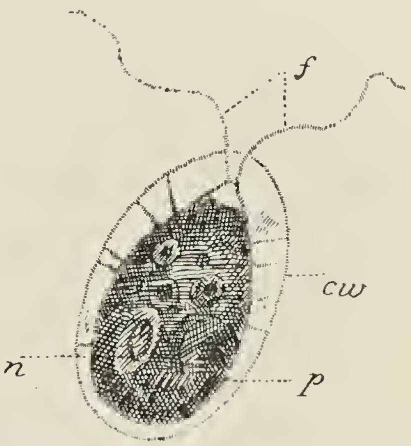


Fig. 9*b*.—A zoospore greatly magnified, showing (*cw*) cell-wall; (*p*) protoplasm; (*f*) flagella arising from clear part of protoplasm and piercing the cell-wall; (*n*) nucleus.

The active, *motile* stage is at an end; the giddy childhood time is passed; an autumnal red has blended with the fresh green hue of youth (for the spent swimmers have partially changed their colour); and the adult or *stationary* stage has commenced. You continue to watch one of these quiescent bodies. It has lost its pear shape now, and has grown larger (fig. 9*c*). Presently a process of rearrangement is seen to be going on inside the little membranous sack.

The protoplasmic contents divide into two portions, each of which again divides: and with that there is a fresh formation of protective membrane, for each of the four bodies must have its own cellulose investment, and—note this well!—each weaves its own. And now we have no longer one quiescent body, but four (fig. 9*d*); so that when the outer investing sack in which they are all contained gives way, they emerge as perfect individuals. Each will have its own independent history ere long—perchance a very different history from that of the parent body; for from each may issue, not fully clothed individuals like themselves, but naked, motile bodies, like those from which the parent was evolved, with pear-shaped forms, and scarlet eye-spots, and delicate contractile flagella. Thus the round of life goes on.

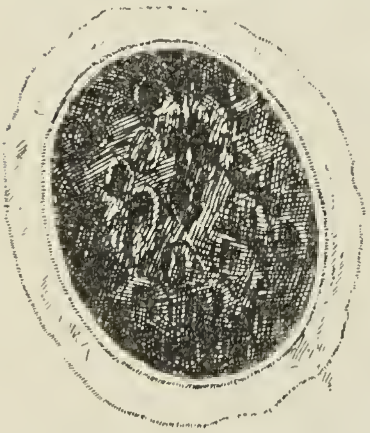


Fig. 9*c*.—A cell which has passed into the "still" condition.

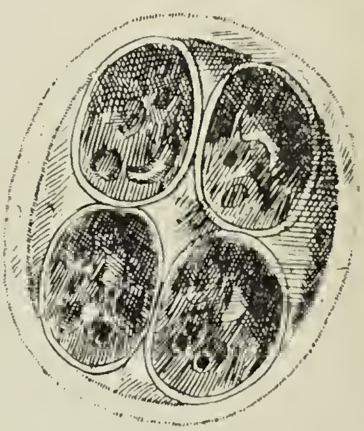


Fig. 9*d*.—Divisions of a "still" cell into four.

But let us pause and ask, What are these changeful little bodies—these minute organisms, so simple and yet so wonderful? To which of the two great realms of living Nature do they belong? Are they animalculæ or plants? "Surely," it might be urged, "they belong to the Animal Kingdom—the little motile bodies tell us that." Yet the fact is otherwise. Those tiny organisms are plants, true plants, and their names must not be sought for in any zoological catalogue. Their habits are, indeed, strikingly similar in some respects to those of many Infusoria (*Vorticella microstoma*, for example); yet are they true plants; and the active little bodies, with red eye-spots and antennæ-like prolongations, are neither more nor less than the motile cells or *zoospores* of our unicellular plant, *Sphærella pluvialis*.

Yes, plants; and each individual is a single cell, though it is only after it acquires its coat of cellulose that it becomes a cell in the common acceptation of the word. It is an *unicellular* plant, and so is distinguished from the great mass of plants, which are *multicellular*, or made up of many cells. And thus we are brought to a very interesting truth, and one of vast importance to the student of Botany—viz., that *every* plant in the wide world, from the highest to the lowest, consists either of a cell or cells, or of the products of their formation and transformation. We shall see farther on that the living matter, or *protoplasm*, as it is called, is the essential part of the cell; indeed, there is evidence of this in the zoospores of *Sphærella*, which, prior to the formation of their coats (properly, *walls*) of cellulose, were simply naked masses of protoplasm. In multicellular plants, where cell-walls are *always* formed, the protoplasm may be used up in the thickening of the wall or transferred to other parts of the plant; but in such cases what remains is still called a *cell.*

The term *cell* appears to have been first used in a botanical connection by the English microscopist, Robert Hooke. Writing in 1665, he says: "Our microscope informs us that the substance of cork is altogether filled with air, and that that air is perfectly enclosed in little boxes or cells, distinct from one another." At that time, and for many years after, the "little boxes" were considered the essential part of the plant; indeed, it was not till the last century, when Schleiden, Schwann, and Mohl in Germany, and Lionel Beale in our own country, proceeded *to look into the little boxes*, that the maintenance of a contrary view became possible. Then began, indeed, the study of Biology, the greatest though youngest of the sciences, which has grown to such wonderful proportions in recent years, though it must still be regarded as almost in its infancy.

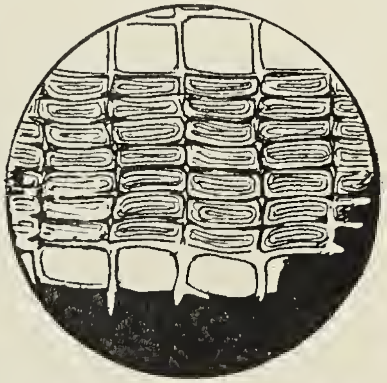


Fig. 10.—Cork cells from a piece of the bark of a Juniper. The shaded cells represent the cork layer.

Until the discovery was made that the protoplasm is the essential constituent of the cell, our knowledge in vegetable physiology could make but slow advances, and a great mass of facts connected with the anatomical structure of plants which the microscope had brought to light, though interesting in a general way, could have but little scientific value. There was much, for instance, to gratify one's taste for the marvellous in the statement that the surface of a square inch of cork contains more than a million cells, and that there are one billion two hundred million in a cubic inch; but the statement by itself has little or no value from a scientific point of view. When, however, we are told (what neither Hooke nor Leuwenhoek, nor any of the older microscopists could have told us) that each of these one billion two hundred million cells originated in a tiny speck of protoplasm, which, after forming for itself—aye, and *from* itself—as our little zoospore had done, a delicate cell-wall, finer a thousand times than the finest gossamer, had proceeded to spread upon the interior of that cell-wall layer after

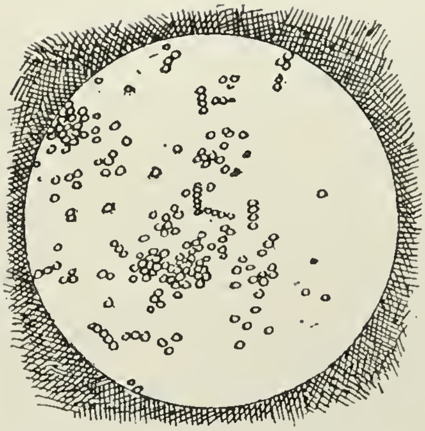


Fig. 11.—*Micrococcus prodigiosus*, commonly known as the "blood portent."

layer of a new substance, which we recognise as suberin or cork, till the "little box" was almost filled up—when these facts were added, it may be said that our knowledge had indeed made great advances.

As allusion has been made to the wonderful minuteness of the cells of cork (fig. 10), it may not be out of place to add a few remarks on the comparative sizes of cells, before we pass on to the consideration of living matter or protoplasm. All cells, with but few exceptions, are microscopically small; mere specks, indeed, and quite invisible to the naked eye. If the task were proposed to us of counting the honeycomb-like partitions in a thin section of the stem of a lily, or the twig of an apple-tree, or a shred of cucumber, or the petal of a rose—and these delicate partitions are so many cells—we should certainly beg to be excused; for the microscope reveals the fact that they are of such minuteness that many thousands might lie, side by side and end to end, on a surface no larger than one's thumb-nail. As a rule, indeed, the cells of all Flowering Plants are extremely small, though certain organs may offer remarkable exceptions. Thus the loose cells (pollen-grains) contained in what are known as the anther-lobes of flowers, are occasionally of an unusual size, some measuring $\frac{1}{10}$ of an inch in diameter; though it should be added, as a matter of comparatively recent discovery, that the pollen-grains of a large number of plants are now known to be multicellular. In any case, the size given is exceptional, and frequently the grains do not exceed $\frac{1}{2000}$ of an inch.

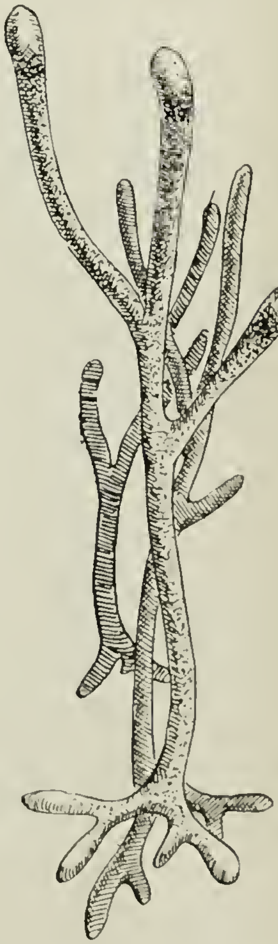


Fig. 12.—Long branched tubular cells of *Vaucheria clavata*, an unicellular plant. Three distinct plants are shown in the drawing.

Some of the tiniest organisms visible under the microscope are the unicellular *Micrococci* (a genus of the Schizomycetes or "fission Fungi" *)

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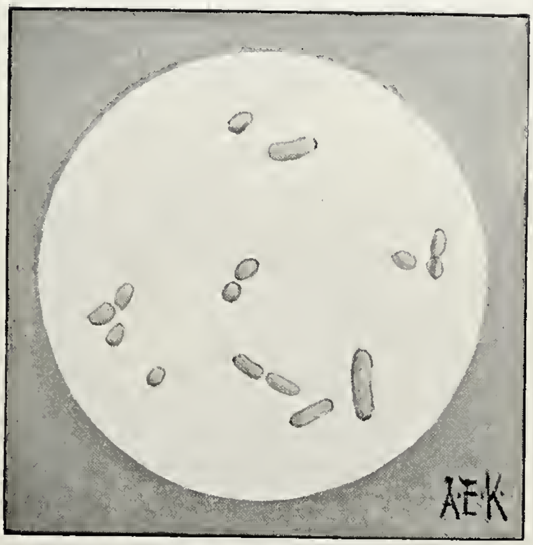
* So called because they multiply by a simple division of the body.



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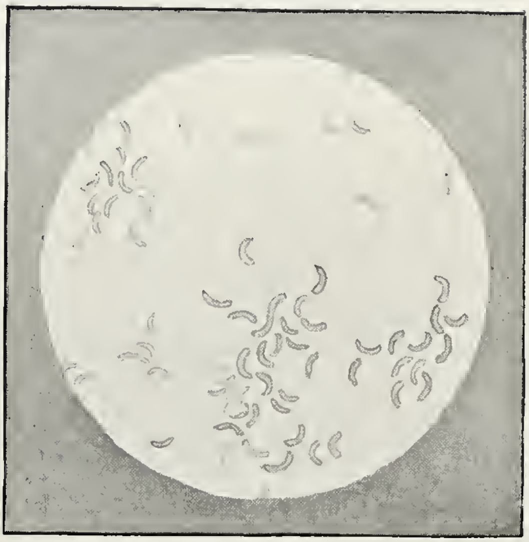

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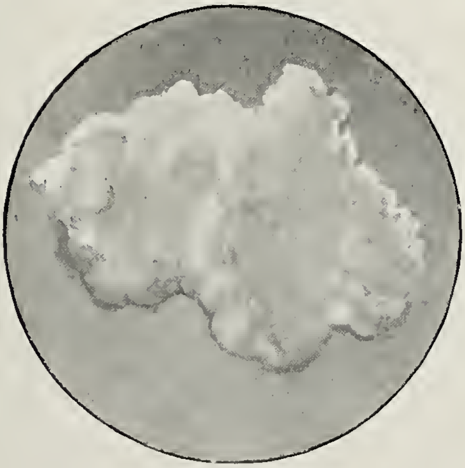

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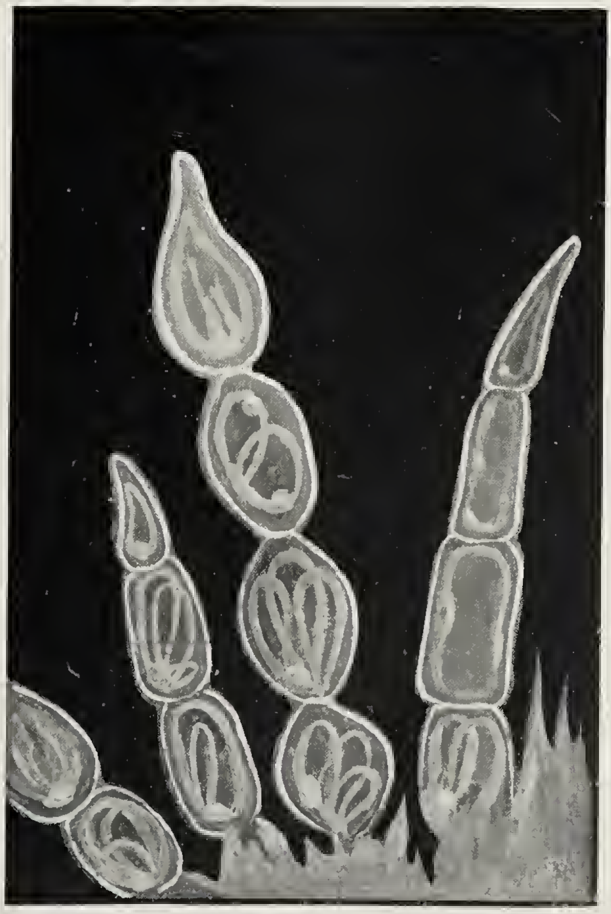

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1. Bacillus (*Kitasato*) of Bubonic Plague, with Flagella.

2. Common Bacillus (*Spirochæte choleræ asiaticæ*) of Asiatic Cholera, with Flagella.

3. A Speck of Protoplasm as seen under the Microscope.

4. Microscopic View of Beaded Hairs of *Tradescantia virginica*, showing Rotation of Protoplasm.

The bright spots in the streams of protoplasm are the nuclei.

Plate VI.

—spherical plants whose diameters vary from $\frac{1}{25000}$ to $\frac{1}{12500}$ of an inch (fig. 11); and along with these may be placed those scarlet river-plants (allied, doubtless, to our rain-water *Sphærella*), many millions of which, as Freycinet and Turrel tell us, might swim without discomfiture in a drop of water! The Schizomycetes form an interesting group, for they include the *Bacteria*, *Bacilli*, and other formidable organisms, to which many of the deadliest diseases are believed to be due.* The microscope has revealed no minuter organisms than these. Countless thousands of the dreaded *Kitasato* bacillus (Plate VI.), which is parasitic in the human body and causes bubonic plague, could, it is said, find lodgment on a needle's point; while their rate of multiplication is so extraordinary that *many millions of millions* may be produced from a single individual in a few hours! Surely we are here approaching the Infinite!

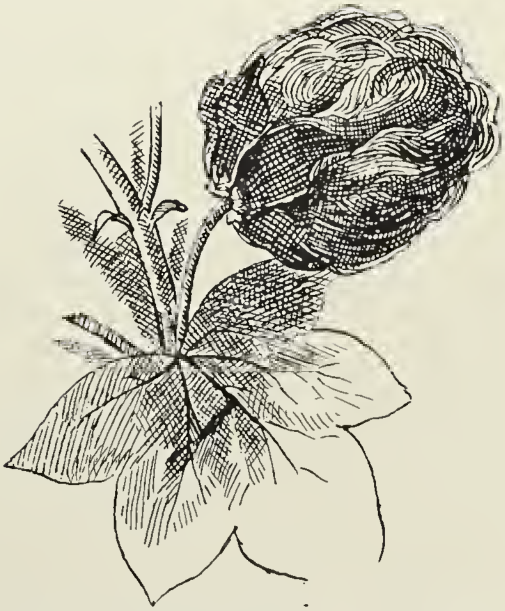

Fig. 13.—Fruiting branch of Cotton-plant (*Gossypium herbaceum*).

In contrast to the Schizomycetes may be mentioned the *Nitella*, an interesting fresh-water plant, which has cylindrical cells that measure nearly two inches in length and $\frac{1}{25}$ of an inch in breadth; or such unicellular algæ as the Vaucheriaceæ † (fig. 12) and Siphonocladaceæ, where the individual consists of a remarkable branched cell, greatly in excess of this. Each of the soft hairs which cover the seed of the Cotton-plant (fig. 13), and which are spun into cotton, is in reality a long cell. This may be readily seen by unravelling a thread of reel-cotton and placing it under the microscope.

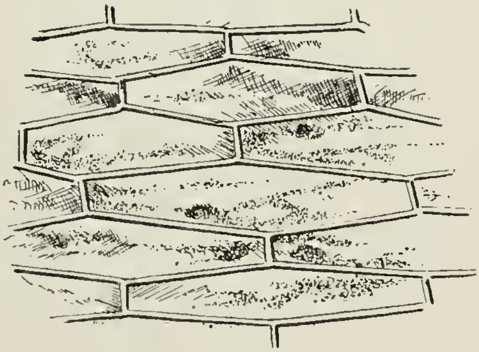

Fig 14.—Cells of Onion.

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* *Bacillus anthracis* is the probable cause of anthrax in cattle, etc.; *B. tuberculosis* of consumption; *Spirochæte choleræ asiaticæ* of Asiatic cholera (Plate VI.); and various other species of bacteria are associated with leprosy, relapsing typhus, footrot, etc.

† Vaucheria is a fresh-water alga. Perhaps it is hardly fair to compare the branched multinucleate body of Vaucheria with a simple cell.

In commencing the study of cells an excellent object for microscopic examination is the thin skin which covers the inside of the fleshy scales of the common onion. The object depicted in fig. 14 consists of a small fragment of this delicate membrane, mounted in balsam. Observe that it is made up of a number of hexagonal or six-sided figures, on the interior of which is an irregular granular substance. Each of these hexagons represents a perfect cell; its sides are cell-walls, and the granular matter in each is *protoplasm.*

Protoplasm in its natural state is colourless and transparent—so transparent as only to be distinguished with difficulty under the microscope. To make it more apparent the specimen is soaked in iodine solution, which has the effect of staining living protoplasm brown, while it tinges with pale yellow the lifeless walls of cellulose. The pale yellow is hardly noticeable by lamp-light; but if a drop of strong sulphuric acid is run under the cover-glass at the time of preparing the slide, the cell-walls become coloured blue. It is by the use of these and other reagents that the organic elements of cells and tissues are distinguished. The word "protoplasm" appears to have been first used by Purkinje* in 1840, to denote the formative substance of the animal embryo, which he compared with the soft cellular tissue (cambium) between the wood and the bark of trees. Mohl, a few years later (1846), applied the term to the contents of the vegetable cell.

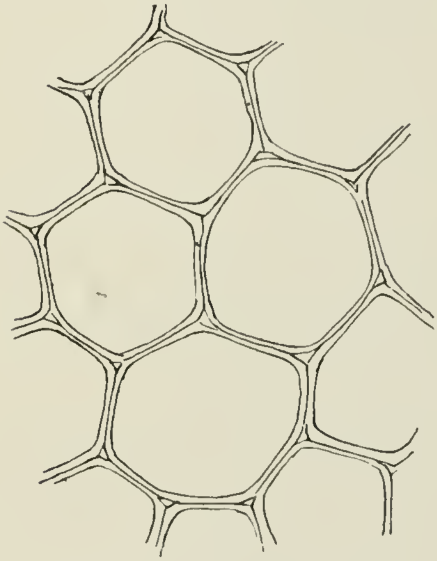

Fig. 15.—Young cells from stem of Traveller's Joy (*Clematis Vitalba*), with walls of cellulose.

It will be noticed that the protoplasm of each of the onion cells contains a small spherical or oval mass, which takes a darker brown than the surrounding matter when treated with the solution. The darker colour is due to the greater density of the protoplasm at these points; and these denser portions envelope a sort of kernel—the *nucleus* (Lat. *nux*, a nut or kernel), which consists of a network of threads, or *fibrillæ*, embedded in a semi-fluid substance known as *nucleoplasm.* The nucleus is not, however, a necessary element; protoplasm may live, and move, and do work when no nuclei are present.

Once these cells were living cells—not, indeed, alive in every part, for that could be said of nothing that lives; but they were living cells. Each cell was a life-unit, for the mysterious principle of Life was in each; and the protoplasmic contents of the cell, *not the cell-walls*, constituted the life-matter. Out of this apparently structureless matter the cell-walls were formed, much as were the cellulose investments of our self-dividing *Sphærella*· for in each case the protoplasm was the vital, active, formative element of the cell. Did, then, these cell-walls cease to grow when once they had been formed? By no means. Yet their growth was due, not to any principle of Life within themselves, but to the introduction of fresh particles of cellulose among those already existing. And these fresh particles were formed and added by the protoplasm.

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* The substance itself was first noticed and described by Roesel v. Rosenhof in his account of the Proteus-animalcule, and was named *sarcoda* by Dujardin in 1835.

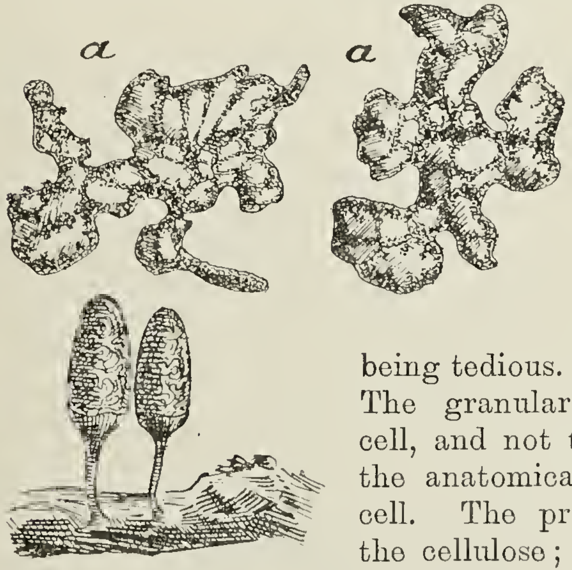

Fig. 16.—One of the slime fungi (*Arcyria punicea*). (*a*) The plant in the plasmodium stage. Each of the bodies is a mass of naked protoplasm with several nuclei. (*b*) Two ripe sporangia of the same.

The history of our fragment of onion-skin is not singular. What was once true of this little cluster of cells, packed together in a space no larger than a Lupine seed, is true of all living organisms whatsoever, whether in the Vegetable or the Animal world (fig. 15). The protoplasm is the essential part of the cell. We would press this, even at the risk of being tedious. It is a point of all-importance. The granular, structureless contents of the cell, and not the wall of cellulose, constitute the anatomical unit, the elementary part or cell. The protoplasm elaborates from itself the cellulose; the cellulose does not form the protoplasm. Cellulose, indeed, is formed from three of the elements which enter into the composition of protoplasm—namely, carbon, hydrogen, and oxygen. The formula is $C_6H_{10}O_5$. Here, then, is proof from chemical analysis. When our *Sphærella* was at rest at the bottom of the drop of water, the source of all the vital changes, it will be remembered, was the protoplasm, not the membranous coat that invested it. Through this delicate coat, it is true, was drawn in from the surrounding water the inanimate material which was required for the nourishment and metamorphoses of the plant; but the interior substance was the active agent, the protoplasm was the drawing power; indeed, the same work went on when the plant was a naked cell, without any cellulose investment whatever.

And this leads us to another important phenomenon in cell-building

—the conversion of lifeless into living matter. Deeply interesting is the power which the protoplasm possesses, not only of building up formed material from itself, but of transforming the inanimate material or pabulum which it draws to itself into living matter! There is nothing in the whole range of Nature more wonderful. A tiny speck of matter (fig. 16)—viscid, transparent, and, so far as the highest powers of the microscope can inform us, structureless—is able to produce matter like itself—living, formative matter—out of the non-living inorganic material by which it is surrounded! Yet the two are quite distinct. The difference between the minute speck of protoplasm and that which nourishes it is absolute. Nor does the one pass by delicate gradations into the other. The change from the non-living to the living is instantaneous. No less absolute is the distinction which exists between living matter and the formed cellular material which is produced by it. The passage from one state into the other is sudden and abrupt; matter cannot be said to half live or half die. Thus a ceaseless round of change goes on—an endless metamorphosis of the lifeless and inorganic into the living but structureless, and of the latter into inanimate and formed material.

The wonderful movements of protoplasm have been often observed, and perhaps no plant has been more studied for this purpose than the Common Spiderwort or Flower-of-a-Day (*Tradescantia virginica*). If we remove a single hair from a stamen of this plant by tearing off a portion of the cuticle to which it is attached (thus avoiding injury to the hair itself), and place the object in a drop of water under the microscope, we may watch for ourselves two of the most characteristic movements of protoplasm. Presuming that we have been fortunate in a choice of specimen, we shall find that the hair consists of three or four cells, of which the shortest and broadest is at the base (Plate VI.). In this cell the protoplasm will shortly be seen to be moving in several elliptical currents from a common point, the nucleus; while in the other cells it will be seen to travel round the cell-walls, though the nuclei, as before, will be the points of departure and return (Plate VI.). The former kind of movement is known as *circulation*, the latter as *rotation*.

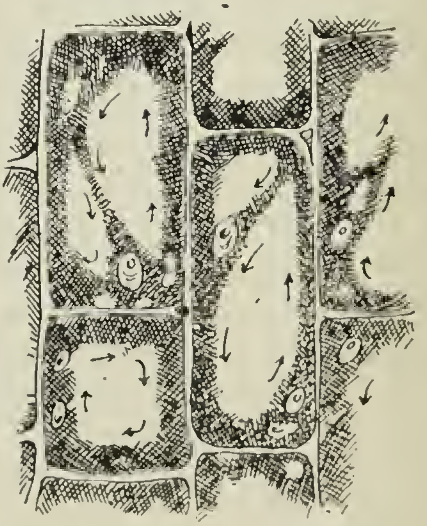

Fig. 17.—Cells from a leaf of Water-thyme (*Elodea*), showing the directions of the currents of protoplasm.

Rotatory movement may also be well seen in certain cells of the Water-thyme (fig. 17) and the grass-like leaves of that river wonder, *Vallisneria spiralis*; for here there are no stationary nuclei, but the whole of the protoplasm moves round and round. In some instances this movement is found to take place in opposite directions in contiguous cells, observation of this interesting fact being facilitated by the presence in the transparent protoplasm of minute corpuscles of a green colouring matter (chlorophyll), which are carried round with the stream, and thus discover its course. The layers of living matter in which these corpuscles float are frequently no more than $\frac{1}{20000}$ of an inch in depth! What, then, must be the dimensions of the corpuscles themselves?

Probably enough has now been said, at least for the present, about the remarkable properties of protoplasm. We have seen that the little specks of germinal matter—the protoplasts, if you please—are the weavers of the warp and woof of organisms—the builders, may we not say?—of all animal and vegetable structures whatsoever. They constitute, indeed, "the physical basis of life," and are the fabricators of every terrestrial object that lives or has lived!

Is it not wonderful to think of our little protoplasts even as the builders of a single plant? Conceive of them, for example, as the fabricators of a Common Briar-rose. Here a number of them are busy at work in their self-formed cells, and they throw out material—as what? As incipient hairs. Here are numbers more equally as busy, and they are producing material which will be built up into woody fibre. Others, close at hand, are constructing a wonderful layer of similar cells, each with its own protoplasm, its own walls, its own cell-sap. Thus in one part of the plant we have our root-hairs; in another, our woody fibre; and in a third, some delicate tissue of cells which is to aid in the formation of a petal, a foliage leaf, or perchance a seed. All this, remember, in a single plant! Yet the little workers are chemically alike in each case; and all consist of the same elementary substances.

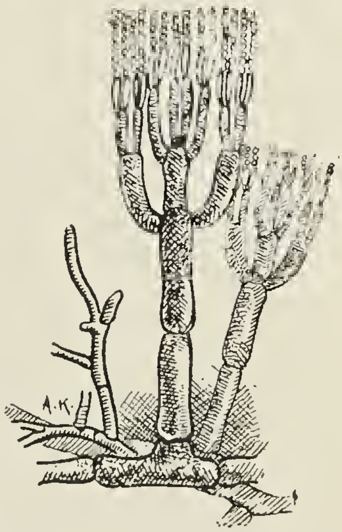

Fig. 18.—*Penicillium glaucum*: a fungus.

And as with our sample Briar-rose, so is it with *all* plants. The chemical constituents of protoplasm are the same wherever you find it; in the simple Fungus (*Penicillium glaucum*) (fig. 18), which forms the green mould on mouldy food, as in the complex organism of a Trumpet-flower or an Orchid.

CHAPTER II

THE PROTOPLAST AS HOUSE-BUILDER AND HOUSE-FURNISHER

Moreover, the walls of the cells themselves are the work of the protoplasts, and it is not a mere phrase, but a literal fact, that the protoplasts build their abodes themselves, divide and adapt the interiors according to their requirements, store up necessary supplies within them, and, most important of all, provide the wherewithal needful for nutrition, for maintenance, and for reproduction.—KERNER.

THE subject of our last chapter was protoplasm, that wonderful substance which Beale calls the "vital element" of organic bodies, and which Huxley has well defined as the "physical basis of life." We now propose to advance a step farther, and to speak of some of the wonderful results of protoplasmic activity—in other words, of the cells themselves (Hooke's "little boxes," if you please), as well as of the changes which they undergo, and of the various substances elaborated within them.

It will be evident to the least reflective mind that these changes must be considerable, otherwise there would be no accounting for the infinite diversities of form, structure, and properties which the Vegetable world presents. For, since the most complex organisms are only the products of cell formation and transformation, and all cells in their beginnings are so much alike, the changes must be vast indeed that produce those diversities—that give us, for instance, in one case a stalk of Wheat, in another a spreading Oak, and in a third a Mushroom.

It will be remembered that the resting spore of our rain-water plant was almost round, while the cells of the piece of onion-skin were hexagonal, and those of the staminal hair of *Tradescantia* were in two cases oblong, in a third almost spherical, and in a fourth triangular: four distinct shapes in a less number of minute objects — inferential evidence, surely, that the forms of cells may vary greatly.

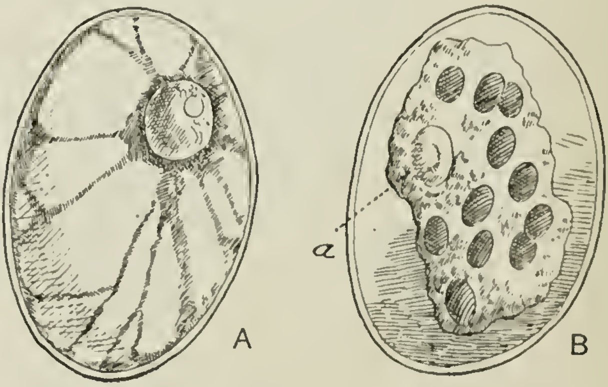

Fig. 19.—A: Oval cell from fruit of Snowberry. B: Oval cell from leaf of Pink. (*a*) Nucleus.

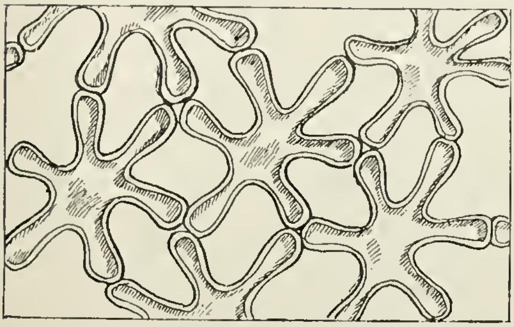

Fig. 20.—Stellate cells of the Common Bean.

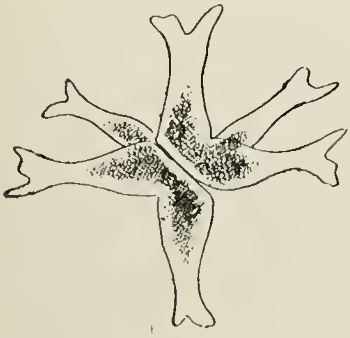

Fig. 21.—A Desmid.

The round shape occurs in most cells at a certain stage (*not the earliest stage, when they are contiguous at all points*), but in few cases, comparatively, is this shape retained. The pressure of contiguous cells as growth continues again effects changes, so that we get octagons and twelve-sided forms, and sometimes cells of no definable shape at all. This may be simply illustrated by getting several balls of soft clay and uniting them by gradual and uniform pressure. The fruit of the Snowberry (*Chiococca racemosa*, fig. 19) and the leaf of the Common Pink (*Dianthus Caryophyllus*) offer interesting examples of cells retaining the spherical—or more correctly oval—form. The pulp enclosed by the outer membrane of the berry of the first-named plant, even when full grown, consists of a vast number of minute shining white granules, each of which is a perfect and almost spherical cell.

The numberless departures from the rounded shape are not all due to pressure, however. Some cells remain long and narrow through their whole history, as those of the hairy seed-coat of the Cotton-plant, to which reference has been made; and others—to wit, the hairs on the leaves of the Virginia Stock (*Malcolmia maritima*) and the Hop (*Humulus Lupulus*)—are curiously branched. Stellate or star-shaped cells are also met with, being found in the stems of many aquatic plants; their rays are seldom very regularly placed, and they vary in length

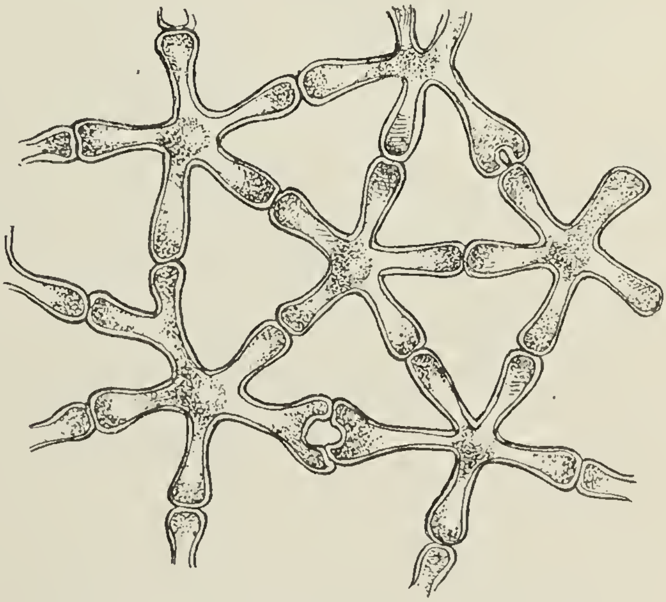

Fig. 22.—Stellate cells from stem of the Common Rush.

on the same individuals. The stellate cells shown in fig. 20, which, however, are not those of an aquatic plant, but of the Common Bean (*Vicia Faba*), are fairly uniform. The solitary stellate cell in the next figure (fig. 21) is not so regular. It is a *Desmid*—one of a remarkably beautiful family of unicellular *Algæ.* Good examples of stellate cells are also afforded by the stems of the Common Rush (*Juncus effusus*, fig. 22), as well as by the Flowering Rush (*Butomus umbellatus*), whose handsome rose-coloured flowers, rising above the surface of the water on a stalk two or three feet high, make it deservedly a favourite with lovers of British water-plants.

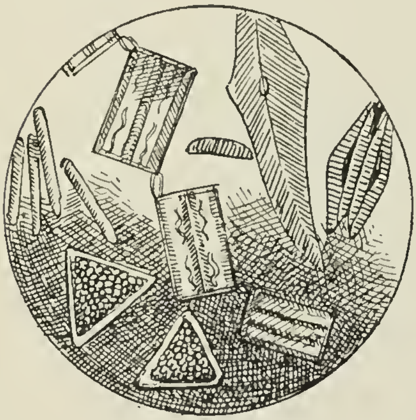

Fig. 23.—Diatoms.

Of more than morphological importance are the facts to be next noticed. "Endlessly diversified in the details of their form and structure," says Professor E. B. Wilson in his fine work on the vegetable cells, "these protoplasmic masses nevertheless possess a characteristic type of organism common to them all: hence in a certain sense they may be regarded as elementary organic units out of which the body is compounded. The composite structure is, however, characteristic of only the higher forms of life. Among the lowest forms at the base of the series are an immense number of microscopic plants and animals, familiar examples of which are the *Bacteria*, Diatoms (fig. 23), Rhizopods, and *Infusoria*, in which the entire body consists of a single cell, of the same general type as those which in the higher multicellular forms are associated to form one organic whole. Structurally, therefore, the multicellular body is in a certain sense comparable with a colony or aggregation of the lower one-celled forms—a comparison, however, which must be taken with some reservation. The comparison is not less suggestive to the physiologist than to the morphologist. In the lower one-celled forms all the vital functions are performed by a single cell. In the multicellular forms, on the other hand, these functions are not equally performed by all the cells, but are in varying degree distributed among them, the cells thus falling into physiological groups or tissues, each of which is especially devoted to the performance of a specific function." (Of this we shall speak more fully in succeeding chapters.) "Thus arises the physiological 'division of labour' through which alone the highest development of vital activity becomes possible, and thus the cell becomes a unit, not merely of structure, but also of function. Each bodily function, and even the life of the organism as a whole, may thus in one sense be regarded as a resultant arising through the integration of a vast number of cell activities; and it cannot be adequately investigated without the study of the individual cell activities that lie at its root."

On looking at a young seedling—say of an Oak (fig. 24) or Chestnut-tree—the question naturally arises, How is it that so small and tender a plant, which may be bent with the finger, is capable of growing into a mighty forest-tree that shall defy the winter storms of centuries? If the cells of which the young plant is formed were, in their beginnings, only so many little specks of protoplasm, each surrounded by a thin diaphanous wall of cellulose, which the shake of a hand would cause to dissolve away, by what mysterious processes has it attained even its present growth? And, still more, how will it develop into the strong-limbed giant which it is destined in future years to become?

The answer—in part, at least—lies in the wonderful property which the protoplasm possesses, not only of building a primary investing wall for itself, but of spreading on the interior of that wall successively new layers of formed material (woody or otherwise in substance, as the case may require) till the cell is all but filled up. This new material, which is found in all Flowering Plants, and in very many Cryptogams or Flowerless Plants, is known as *secondary deposit.* The process which goes on may be likened to the formation of the furred deposit (limestone) on the inside of a kettle. The kettle answers to the cell; the water to the protoplasm; the tin side of the kettle to the primary cell-wall; and the hard limestone accretion to the secondary deposit.

Cellulose itself ($C_6H_{10}O_5$), though it is the material of which the primary cell-wall is formed, is very seldom found as a

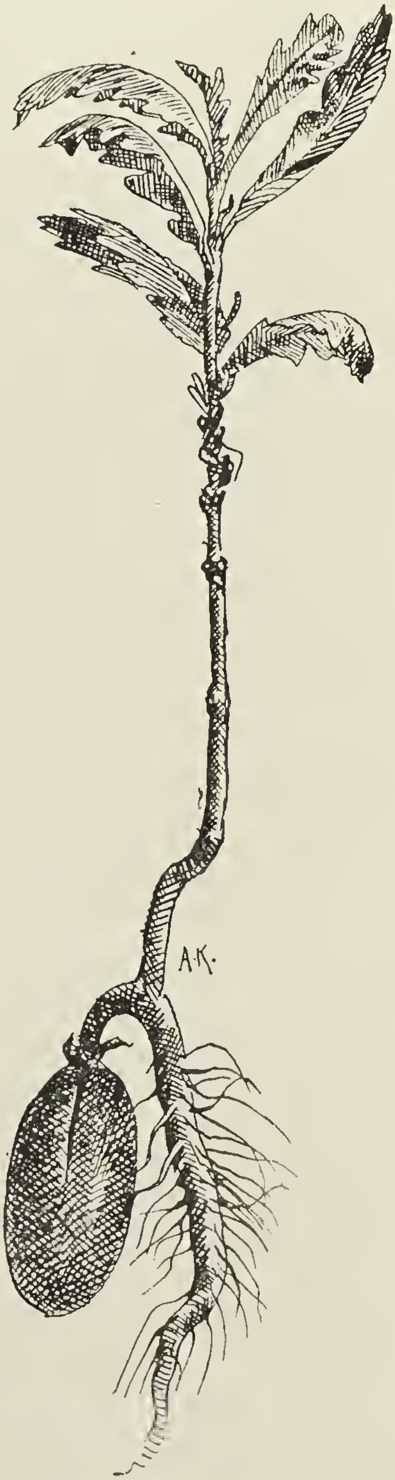

Fig. 24.—Seedling of Oak.

secondary deposit. The date-stone may be cited as an interesting exception. The thickening which takes place in the interior of the cells of the plum and cherry—we do not speak of the stones of those fruits—and in the pith of certain plants of the Pea family, is a gum; whilst mucilage, a kind of gum, is found in the cells which form the seed-coat of linseed, the apple, pear, etc. A very common and important kind of secondary deposit is *lignin*, which, as might be guessed from the name (Lat. *lignum*, wood), is found in all woody cells. The stones and shells of many fruits are built up of such cells; and woody tissue of course abounds in the stems and branches of trees. Lignin, like all secondary deposits, is derived from the protoplasm, which, as the cell-wall increases in thickness, becomes more and more restricted in its movements, until at last it is crowded out, if one may so say, and dies. Great honour is put upon the cell after death, however; it is dignified with a new name—a name of sixteen letters—as inelegant as it is long. The lifeless structure becomes, in fact, a *sclerenchymatous* cell—the name implying that the cell has had something hard put into it; for the term is derived from two Greek words—*sklēros*, hard, and *enchuma*, anything poured or put in.

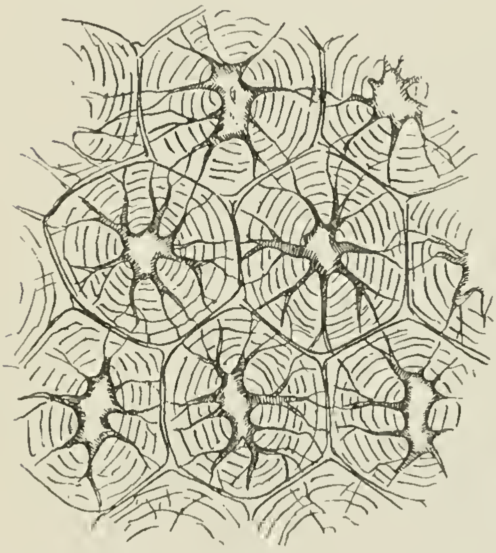

Fig. 25. — Wood cells from the gritty centre of a Pear, forming what is known as sclerenchymatous tissue.

Sclerenchymatous cells occur in the gritty centre of the pear (fig. 25), in the stones of the peach, cherry, etc., and in the shell of the common hazel-nut. Lignin takes a deeper yellow than cellulose when treated with iodine (cf. p. 16), and it becomes brown when treated with iodine and sulphuric acid.

Suberin, or cork substance (Lat. *suber*, cork), is another of the secondary deposits of cells. Like cellulose and lignin, it is coloured yellow by iodine, but it resists the action of sulphuric acid. Cork cells are tough without being woody. Parts of plants the fluids of which require to be protected from evaporation, are usually surrounded by cork cells, as the stems and older branches of trees, in which the sap circulates. In young and quickly growing trees the epidermis (outer skin) of the stem, being unable to stretch fast enough, often gets torn, and then the busy protoplasts cover the wound with a special layer of cork cells. The thick, rough, cleft bark of a Spanish species of Oak

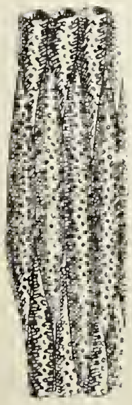

Fig. 26. —Pitted wood cells from a Bignonia.

(*Quercus suber*) is the cork of commerce, of which the stopples for bottles and casks are made. It is stripped off without injury to the stem—which, indeed, soon gets covered with fresh layers of corky cells, and in eight or ten years the tree is again ready for stripping. The first peeling takes place when the tree is twenty-five or thirty years old, and great care is always taken not to injure the inner bark.

Earthy or *mineral* substances, found in all plants, abound in some forms of secondary deposit, and may be readily detected when any part of the plant containing them is burned. The ash left after burning is commonly known as "the ash of plants," and consists chiefly of silica, lime, and magnesia. *Silica* (flint) is particularly plentiful in the grasses, canes, etc., the glassy appearance of the stems of such plants being due to the presence of this mineral. Years ago, a melted mass of glassy substance—at first supposed to be a meteoric stone—was discovered in a meadow between Mannheim and Heidelberg in Germany; but when chemically examined it was found to consist of silex combined with potash. Upon inquiry it was ascertained that a stack of hay, which had been recently destroyed by lightning, had stood on the spot. The siliceous mass was simply the ash that remained after the conflagration. One cannot reduce haystack burning to a system for purposes of experiment, but instructive results may be obtained on a small scale by igniting a piece of siliceous tissue on platinum foil, after soaking in nitric acid. If the ash is then treated with the same acid, it will show an insoluble residue, and that residue is flint.

It frequently happens that the protoplasm deposits secondary thickening only in some parts of the cell-wall, the other portions being left bare. For this reason we get some curious varieties of cells. Thus, in what are known as the *pitted* or *dotted* cells, the secondary deposit is spread upon the cell-walls so as to leave little pits, open at the interior side of the cell, and closed at the exterior by the primary cell-wall. These pits have the appearance under the microscope of transparent specks (fig. 26). When several dotted cells come together, it often happens that the pits of their contiguous walls are coincident; and the utility of this very beautiful arrangement is at once evident: for even after the cells have attained a considerable thickness, they are still permeable to the fluid from without, which is taken in through these little pores and used up by

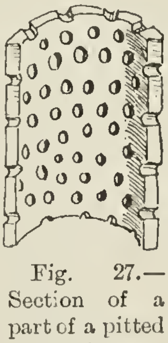

Fig. 27.—Section of a part of a pitted cell (diagrammatic).

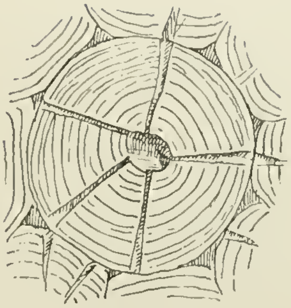

Fig. 28.—Cell from the bark of a New Zealand Conifer (*Podocarpus dacryoides*).

the imprisoned but still living and working protoplasts (figs. 27, 28, and 29).

In certain plants of the Cactus order (as *Melocactus*, *Mamillaria*, and *Opuntia*), the wood is entirely composed of short spindle-shaped cells, in which are elegant spiral bands of secondary deposit, looking, as Schleiden neatly expresses it, "like little spiral staircases" (fig. 30). We call these *spiral* cells. The large elongated leaf-cells of the Bog-moss (*Sphagnum*) and the leaf-cells of many orchideous plants have spiral fibres loosely coiled in their interior; but a better plant than either Orchid or Bog-moss for studying these spirals is the Wild Clary (*Salvia Verbenaca*), a portion of the seed-coat of which makes an extremely interesting object under the microscope. If a very thin slice of the outer coat, moistened with a drop of water, be placed between the glass slides, the delicate fibres will be seen to break through the membranous cell-wall—a proof of their remarkable elasticity. In most spiral cells that have been examined the fibres wind from left to right; and it has been suggested with some show of reason that the direction of the twining stems of plants may have definite relation to the direction of the spirals. This would certainly appear to be the case in the Hop (*Humulus Lupulus*), which is a right-handed climber and always has right-handed spirals. *Saccolabium guttatum*, an East Indian species of epiphytal Orchid, has fibres which wind in opposite directions, but this is not a twining plant.

A fair idea of a spiral cell may be obtained by placing a coil of fine wire in a tightly enclosing glass tube of the same length as the coil, and covering up the ends with glass discs. In Nature the fibres are extremely delicate, their diameters being in some cases less than $\frac{1}{12000}$ of an inch; and as a rule they are quite transparent and colourless. Nevertheless, they may—and do—vary considerably in thickness; and in most plants of the Lily order, and also in the Elder (*Sambucus*), the coiled-up threads may be seen with the naked eye. If the stem of a Lily be partly cut across

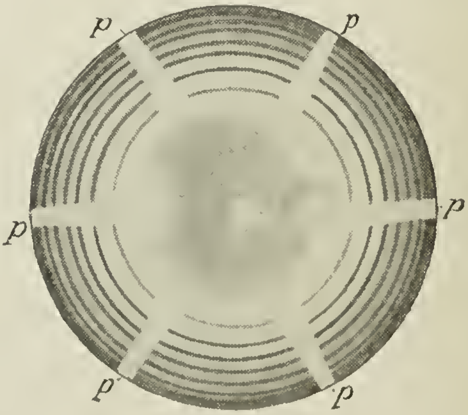

Fig. 29.—Diagram to illustrate the disposition of layers of secondary deposit in porous cells. (*p*) Pores. The broken rings represent successive layers of secondary deposit. The protoplasm occupies part of the central space.

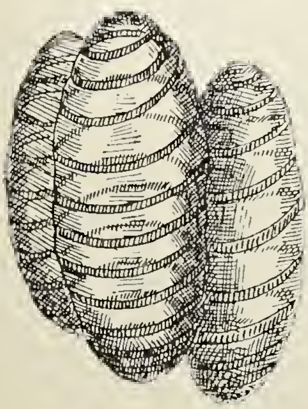

Fig. 30.—Spiral cells of Mistletoe.

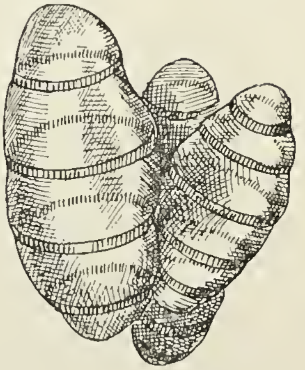

Fig. 31.—Annular cells of Mistletoe.

and then gently broken, the chances are that the broken pieces will be held together by some of these delicate threads; and they will probably be found to be strong enough to support the weight of one of the fractured pieces, if the piece in question be not too large. It is wonderful to think that though some of the cells which contain them measure only $\frac{1}{3000}$ of an inch in diameter, the tiny spirals may consist of several distinct threads; indeed, the contiguous coils in some cases have been found to number more than twenty! How carefully Nature prepares her work even when the objects of her skill are invisible to the unaided human eye!

The fibrous spirals in the leaf-cells of many Cone-bearing plants (*Coniferæ*) have been pressed into the service of man, being found to afford an excellent substitute for wool and cotton. In 1842 a quantity of woven fabric of this material was introduced in place of cotton in the hospital at Vienna, where, after several years' experiment, it was renewed. Similar success attended its introduction into prisons and hospitals at Berlin, Breslau, and other places. When used in mattresses, it is found to last three times longer than wool; while for spinning and weaving purposes it has the strength of hemp, and so may be profitably employed in the manufacture of carpets and blankets.

Sometimes the thickening of the cell-walls takes the form of rings, as in the Mistletoe (*Viscum album*) and many grasses; and thus we get *annular* cells—a name derived from the Latin *annulus*, a ring (fig. 31). Three or four indiarubber rings fitted tightly in a short cylindrical lamp-glass give the idea. Not infrequently the rings appear to have their beginning in spiral fibres, which, in consequence of their rapid growth, get broken in places, and so fall together in rings; indeed, the transition from the spiral to the ringed form has been observed in certain plants, notably in the Opuntias, that well-known genus of the Cactus order to which the Prickly Pear (*O. vulgaris*) belongs. They are plentiful enough, too, in the leaf-stalk of the Common Ivy (*Hedera Helix*). Cells containing these composite fibres are described as *spiro-annular*.

Another modification of the true spiral is found in *reticulated* cells (Lat. *reticulum*, a small net), where the bands of thickening are arranged in a net-like manner on the interior of the primary walls. By this disposition of the secondary deposit, little trenches are left at variable distances, which appear under the microscope like more transparent lines. The Touch-me-Not Balsam (*Impatiens Noli-tangere*) and the Mistletoe (*Viscum album*) furnish interesting examples of reticulated cells (fig. 32).

"It is scarcely possible," says Dr. Carpenter in his *Vegetable Physiology and Botany*, "to observe the number of different forms resulting from the varied combinations of the simple elements, each of them probably having its peculiar function in the Vegetable economy, without being struck with the simplicity of the plan by which Creative Design has effected so many marvels, as well as with the extreme beauty and regularity of the structures which are thus produced. The comparison of such specimens of Nature's workmanship as the meanest plant affords, with the most elaborate results of human skill and ingenuity, serves only to put to shame the boasted superiority of man; for whilst every additional power which is applied to magnify the latter serves but to exaggerate their defects and to display new imperfections, the application of such to organised tissues has only the effect of disclosing new beauties, and of bringing to light the concealed intricacies of their structure."

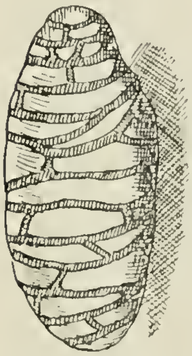
Fig. 32.—Reticulate cells of Mistletoe.

But it is time to pass from this subject. We trust that we have now treated with sufficient fulness the more important facts connected with the thickening of the primary cell-wall by means of secondary deposit; and that some definite idea has been conveyed of the manner in which cells—though not *all* cells—are made strong and hard and capable of firm resistance. We will now consider some of the other substances produced in vegetable cells as the result of protoplasmic activity.

In treating of the movements of protoplasm in *Vallisneria* (p. 19), allusion was made to the minute green corpuscles contained in the living matter of the long grass-like leaves, and carried round with it in the cells. These little bodies are known as *chlorophyll corpuscles* or *chloroplasts* (fig. 33), and the green colouring pigment chlorophyll—a name derived from the Greek *chloros*, green, and *phullon*, a leaf. Many millions of such corpuscles exist in every full-grown plant of *Vallisneria*; though that circumstance alone is not our warrant for returning to the subject. If chlorophyll were only distributed in the tissues of a few water-plants, it would call for no special mention there; but the contrary is the case. As a matter of fact, these tiny bodies of coloured matter constitute one of the most widely distributed of vegetable substances, being found in all green plants; while their essential identity with protoplasm gives them an especial interest. Chlorophyll corpuscles have, indeed, been defined as specialised masses of protoplasm coloured green, and no definition could be more clear, concise, and satisfactory. It is thought that they possess a reticulated structure, and that the colouring matter occupies the meshes of the network in a state of solution. Chloroplasts are not found in animals, save, indeed, in some of the Flagellata, which are nearly connected with the lower green Algæ, and occasionally as a foreign product. The latter exception needs to be recorded, since it was long held that the chloroplasts contained in the tissues of the fresh- and salt-water Sponges, and the fresh-water *Polypus*, belonged to those animals.* Professor Weiss has shown that they are really vegetable cells which may be cultivated outside the animal body. "As," says he, "these green cells can form starch and ultimately sugar, which transfuses out of the *Algæ* into the body of the animal, it is evident that they are of real benefit to the animal, while the *Algæ* themselves can absorb certain substances out of the animal cells. An analogous example occurs in the Vegetable Kingdom in the case of the Lichens, in which some green *Algæ* are associated with a Fungus. Every Lichen consists of the two different organisms, and the green cells form, under the influence of light, food substances which are made use of by the Fungus. In initial stages the Fungus can be seen capturing, with its threads, the *Algæ* cells of which it makes use, and which are the working partners of the concern" † (fig. 34).

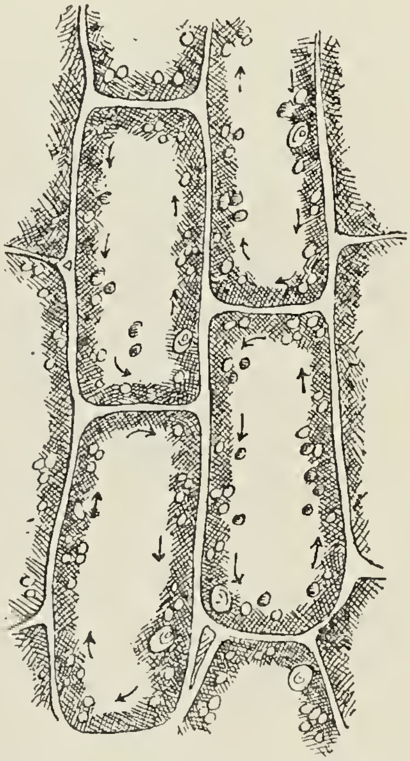

Fig. 33.—Cells from a leaf of *Vallisneria spiralis*, showing chloroplasts (the oval bodies) in the protoplasm.

Under the microscope the chloroplasts have usually a globular appearance, but instances occur in which they are quite formless. In the well-known Water-thyme (*Elodea canadensis*), so execrated by bargemen and water-mill owners, they are irregular in shape, some presenting the appearance of circular flattened discs, while others are spherical and oval. Their diameters vary from $\frac{1}{3000}$ to $\frac{1}{5000}$ of an inch. Of the colouring matter diffused through the corpuscles, we have as yet no certain knowledge, but the opinion still held by very many that it is composed of two independent colouring substances—a golden-yellow and a blue-green—is now abandoned by the highest authorities. Those substances are, indeed, the products of the *decomposition* of chlorophyll, but chlorophyll itself is a single pigment.

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* Chlorophyll corpuscles were found in fresh-water Sponges by Professor Ray Lankester, and Mr. MacMunn found them in no less than nine specimens of sea Sponge.

† *Proceedings of the Manchester Microscopical Society*, 1892.

One eminent analyst (Gautier) regards it as related to the colouring matter of the bile; another (Hoppe-Seyler) as a fatty body allied to lecithin, which is a phosphoretted viscous substance entering into the formation of the brain. But "it is extremely difficult," says Dr. Reynolds Green, "to say what is the chemical composition of chlorophyll, on account of the readiness with which it is decomposed. In all the processes which have been adopted for its extraction it undergoes decomposition, and consequently no definite conclusions as to its chemical nature can at present be arrived at. It can be made to yield definite crystals by appropriate methods of treatment after extraction, but it is probable that these crystals are a derivative of chlorophyll, and not the pure pigment." The statement found in many of the text-books that the chloroplasts are coloured blue by iodine is misleading. Iodine denotes the presence of starch-grains, which often occur—*but by no means always*—in the corpuscle.

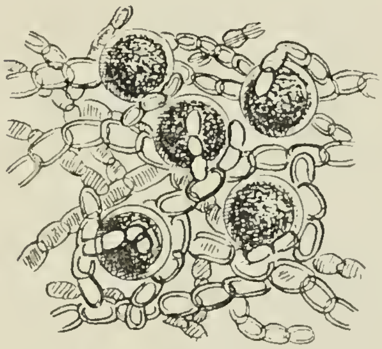

Fig. 34.—Portion of a vertical section of the thallus of a Lichen (*Sticta pulmonaria*), showing hyphæ enveloping a chlorophyll-containing alga. The round bodies are the alga.

Specially interesting is the fact that light is a necessary condition for the formation of chlorophyll. Grow a plant in the dark, and its leaves will be yellow and sickly; bring it forth to the light, and it will become green and healthy. Hence it will be readily gathered that chlorophyll is seldom found in the roots of plants. The roots of the Common Buckbean or Marsh-trefoil (*Menyanthes trifoliata*) may be cited as a curious and—in so far as underground roots are concerned—perhaps an unique exception; but the green aerial roots of some epiphytal Orchids (fig. 35) contain this important substance. The whiteness of celery is due to the exclusion of light from the stem and leaves, which are banked round with earth as fast as they grow. Hindrance is thus offered to the formation of chlorophyll, and by this mode of cultivation the rank coarse taste of the plant is completely removed, and the mild sweet flavour which we associate with table celery is imparted to it. In its natural state celery is a poisonous plant.

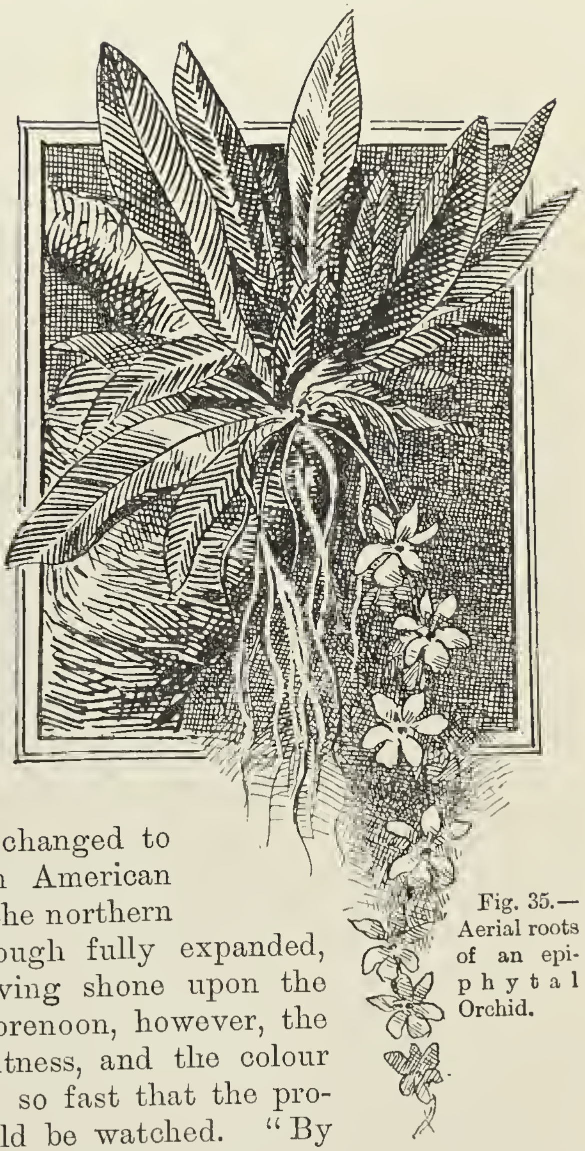

Fig. 35.—Aerial roots of an epiphytal Orchid.

Doubtless the reader will have noticed how quickly the pale unfolding leaves of spring assume their characteristic hue if the weather be bright and sunny; and, on the other hand, how slowly this change is effected during a succession of dark cloudy days. This fact is more remarkable in tropical countries than in England. It frequently happens in America that clouds and rain obscure the atmosphere for several days together, and that during this time the buds of entire forests expand themselves into leaves. These leaves assume a pallid hue until the sun appears, when, within the short period of six hours of a clear sky and bright sunshine, their colour is changed to a beautiful green. Mr. Ellis, an American writer, tells of a forest in one of the northern States, the leaves of which, though fully expanded, were almost white, no sun having shone upon the forest for twenty days. One forenoon, however, the sun began to shine in full brightness, and the colour of the forest absolutely changed so fast that the progress of the transformation could be watched. "By the middle of the afternoon the whole of this extensive forest, many miles in length, presented its usual summer dress."

Often associated with chlorophyll is *starch* ($C_6H_{10}O_5$), which plays so important a part in the nutrition of mankind. "Starch makes the man," said a lady lecturer half a century ago; but she spoke of it in another connection—namely, as the stiffening property in linen articles of male attire. Starch was imported into this country in considerable quantities during the sixteenth and seventeenth centuries, when the enormous ruffs inseparably connected with the Elizabethan and early Stuart periods were in vogue. Gerarde tells us that the best of this starch was obtained from the Cuckoo-pint or Wake-robin (*Arum maculatum*). "The most pure and white starch is made of the roots of the Cuckoo-pint, but most hurtful for the hands of the laundress that hath the handling of it: for it choppeth, blistereth, and maketh the hands rough and rugged, and withal smarting." That dealer in spells and philters, the notorious Mrs. Turner, has the credit of introducing yellow-starched ruffs into Britain, blue and white being the fashionable colours hitherto. Mrs. Turner literally died in starch. In the presence of many women of fashion she "made her exit on the scaffold at Tyburn, rouged and dressed as if for a ball, and wearing an enormous ruff stiffened with her own yellow starch."

The formation of starch is effected by protoplasmic bodies, which may either be the chloroplasts already spoken of or *leukoplasts* (fig. 36) (Greek *leukos*, white, and *plasma*, something formed), which only differ from the former in being colourless. Starch-making chloroplasts are found chiefly in the leaves of plants; leukoplasts in the roots and tubers and certain other parts which are hidden from the light; yet the relationship between the two is shown by the fact that leukoplasts turn green when light is admitted to them for a sufficient time. They take a yellow or yellowish brown stain when treated with iodine, and should be examined under a high power. The starch-grains have the same chemical composition as cellulose ($C_6H_{10}O_5$), but, unlike cellulose, are soluble in water, and will take a blue or violet stain if treated with iodine, which cellulose will not. Their formation may be thus described. The cells containing chlorophyll, which are always near the surface of the plant, absorb carbonic acid gas (CO_2) from the atmosphere or water (the latter in the case of submerged plants), and this gaseous compound reacts with water (H_2O) in the chlorophyll corpuscles under the action of light. The first organic product as a result of this process is, in most plants, *glucose* ($C_6H_{12}O_6$), or some other form of sugar. The sugar has to be diffused along certain delicate cells * of the plant, and as the process of diffusion is too slow to keep pace with the process of construction, another agency is brought into play. The chloroplasts, in short, have *the power of converting sugar into starch*—a power (we quote from Dr. Reynolds Green) which "is quite independent of the colouring matter, being shared by other quite colourless plastids [the leukoplasts already mentioned], which occur in other parts of the plant. The transformation is apparently a process of secretion. Part of

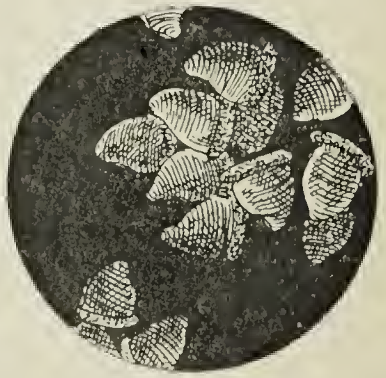

Fig. 36.—Leukoplasts attached to starch grains in the cell of an Orchid.

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* The bast tissue (*vide* Chapter III.)

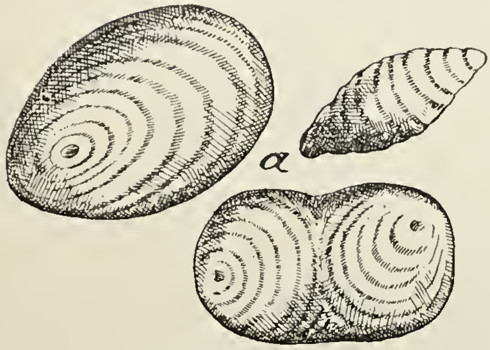

Fig. 37.—Starch grains of a Potato.

the sugar consequently gives rise to numerous minute grains of starch, which the plastid forms within itself, and deposits in its own substance. This formation of a temporary store not only relieves the over-saturation of the sap in the cell, but supplies the need of the protoplasm when the formation of sugar from carbon dioxide and water is interrupted by the failure of the daylight."

In this way, then, do green plants assimilate the carbon which they take into their cells by absorption; and as carbon usually forms one-half of the dried plant by weight, the statement will not appear extraordinary that starch (or its physiological equivalent) is really the raw material from which all the other organic substances of the plant are elaborated.

Starch-grains are found in almost all plants, in every part, but particularly in the roots, tubers, seeds, and fruits, where they are stored up as reserve food material: in fact, they supply the young plant with food till it is in a condition to feed itself. The roots of the Tapioca-plant (*Jatropha Manihot*) yield about 13½ per cent. of this important substance; the tubers of the Potato-plant (*Solanum tuberosum*) nearly twice that proportion (figs. 37, 38); and the seeds of Wheat and Maize about 75 and 85 per cent. respectively. The fruit of *Artocarpus incisa* (fig. 39)—

> The Bread-tree, which, without the ploughshare, yields
> The unreaped harvests of unfurrowed fields;
> And bakes its unadulterated loaves
> Without a furnace—

yields about 3⅕ per cent.

Starch-grains vary considerably in size, according to the plants in which they are found. Some of the largest occur in the tubers of *Canna edulis*, and measure $\frac{1}{300}$ of an inch in diameter. This is the interesting Tous-les-mois starch of commerce. The grains differ very much in form also, but ovoid and lens shapes are most common. Spherical grains are found in the tuberous roots of plants of the Orchid family, and rod and bone shapes in the milk-sap of many tropical Euphorbias (fig. 40). In the

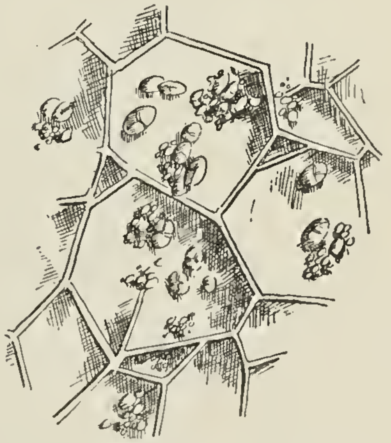

Fig. 38.—Starch grains in broken cells of a Potato.

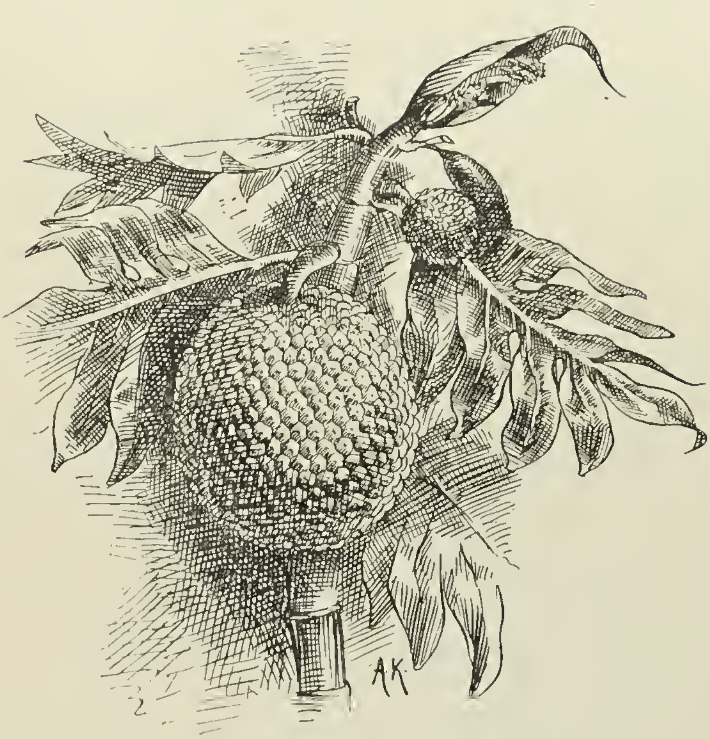

Fig. 39.—Bread-fruit (*Artocarpus incisa*).

Corncockle (*Agrostemma Githago*) they are spindle shaped; and angular starch granules, cemented together to form ellipsoidal grains, are found in the seeds of the Oat (*Avena*) and Rice-plant (*Oryza*).

Closely allied to starch is *inulin* ($C_6H_{10}O_5$), which is found in solution in many roots, tubers, seeds, etc.—particularly of plants of the Composite order. Thus it occurs in the roots of Elecampane (*Inula Helenium*), Dandelion (*Taraxacum officinale*), Chicory (*Cichorium*), and Feverfew (*Matricaria Parthenium*); in the tubers of the Potato-plant (*Solanum tuberosum*), Dahlia, and Jerusalem Artichoke (*Helianthus tuberosus*); and in the seeds of the Sunflower (*H. annuus*) and many other plants. The inulin of the chemist, which is a soft, white, tasteless powder, is usually prepared from Elecampane or the Dahlia. In its natural state inulin is distinguished from starch by giving a yellow or yellowish brown instead of a blue colour with iodine, and by its inalterability under the influence of ferments. It assumes the form of beautiful sphere-crystals on the addition of alcohol, and is coloured an orange-red with alcoholic solution of orcin, after warming with hydrochloric acid.

An earlier occasion should perhaps have been chosen to speak of the *sap* of plants. We propose in the following section to treat of its composition only, reserving a consideration of its functions for future chapters. Cell-sap is the fluid which the roots of plants absorb from the soil, or the leaves from the atmosphere, and which contains in solution the true nutritious principles. Water is the chief constituent of cell-sap, calculations showing

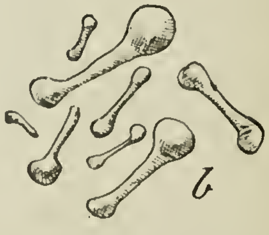

Fig. 40.—Starch grains of *Euphorbia splendens*.

that for every two hundred grains of water absorbed and exhaled by a plant, only one grain of inorganic matter is appropriated; and for every two thousand grains of water consumed, one grain of inorganic matter is appropriated.

Young cells are usually well supplied with sap, which fills the spaces (called *vacuoles*) occurring in the protoplasm. It is conveyed into the plant by the roots, but not till it reaches the leaves does it undergo any important changes. The proof of this must be left for another chapter, our present purpose being simply to speak of the sap as a substance found in vegetable cells apart from the functions which it discharges. Cell-sap may be sweet or acid, clear or turbid, nutritious or innutritious, so that its value from an economic point of view is often great. The refreshing acid taste of most unripe fruits is due to the sap. *Citric acid*—a familiar form of it—gives sharpness to the juices of lemons, oranges, limes, and many of our commonest fruits, as the cranberry, cherry, red whortleberry, and the "hip" of the Wild Briar (fig. 41); and it exists, with an equal proportion of another acid—*malic*—in the cells of the red gooseberry, the currant, the bilberry, the black cherry, the wood strawberry, and the raspberry (fig. 42); while the latter is found alone in apples, pears, etc. As these acids are much disliked by birds and mammals, they serve as a protection to the young fruit, which would otherwise get eaten before the seeds are ripe and ready for dispersion. As the seeds mature, however, a sweetening property is added to the sap, and so the visits of birds and other fruit-eating animals, whose presence is now required, are bountifully encouraged.

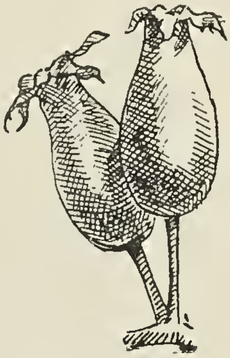
Fig. 41.—Fruit (hip) of Dog rose (*Rosa canina*).

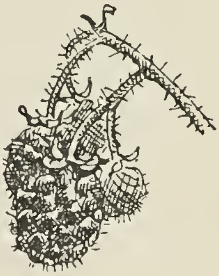
Fig. 42.—Raspberry (*Rubus Idæus*).

The acid juice of *Gymnema sylvestre*, a tropical Asclepiad, destroys or vitiates the taste if the leaves be chewed. A Mr. Edgeworth, who was the first to draw attention to this singular fact, states that "after masticating the leaf, powdered sugar was like sand in the mouth; while a sweet orange had the flavour of a sour lime, the sourness of the citric acid being alone distinguishable. Only sweet and bitter flavours are thus destroyed. This indicates that the action is not due to a complete temporary paralysis of the nerves of taste. After a good dose of the leaf, sulphate of quinine tastes like chalk. The effect usually lasts two or three hours." It has been proposed to call the acid *Gymnaic acid*, after the plant.

The sweet pink cell-sap of the Common Beetroot (*Beta vulgaris*, fig. 43), owes its sweetness to the presence of *Canose* (cane-sugar) dissolved in it. The Prussian chemist, Margraff, was the first to discover this fact (about 1747), but it was not till the year 1809, when Napoleon forbade the importation of West Indian cane-sugar into France, that the discovery was turned to practical account. An Imperial sugar factory was then established at Rambouillet; pupils were regularly instructed in the process; premiums were offered for the best samples of the new sweetener; and, in the course of three or four years, the manufacture of beet-sugar was prosperously set on foot. Canose occurs abundantly in the Sugar-cane (*Saccharum officinarum*) and Sugar-maple (*Acer saccharinum*), and is the substance found in the nectaries of flowers out of which the bees make their honey. It is secreted by the protoplasm of the cells composing the nectaries, and the quantity is at its maximum during the emission of the pollen, but ceases when the fruit is formed. Its purpose is evidently to attract insects or small birds to the plant, and thus to secure fertilisation—a subject of deep interest, which will be considered more fully farther on.

Canose, or Cane-sugar, must be carefully distinguished from *Glucose*, or Grape-sugar. The formula of the first-named is $C_{12}H_{22}O_{11}$, of the latter $C_6H_{12}O_6$; and glucose, as we have already seen, is a result of chemical rather than of protoplasmic action (p. 32). It gives a bulky yellow precipitate with the reagent known as Fehling's solution, which Cane-sugar does not.

No account of the peculiar juices of plants would be satisfactory which excluded a reference to the milk-sap, or *latex*. This fluid, though clear while in the uninjured tissues, instantly becomes turbid on exposure to the atmosphere. The colour of the latex is usually milk-white; but yellow, red, and, in rare cases, blue milk-saps are met with. The microscope shows that it consists of a colourless fluid wherein float myriads of minute globules, which give the sap its opaque appearance. The Dandelion (*Taraxacum officinale*) and Celandine (*Chelidonium majus*) are familiar instances of latex-yielding plants. The latter exudes a bright yellow juice if the leaf or stalk be broken. Lettuces, again, when allowed to run up to flower, yield a white milky fluid; and both caoutchouc

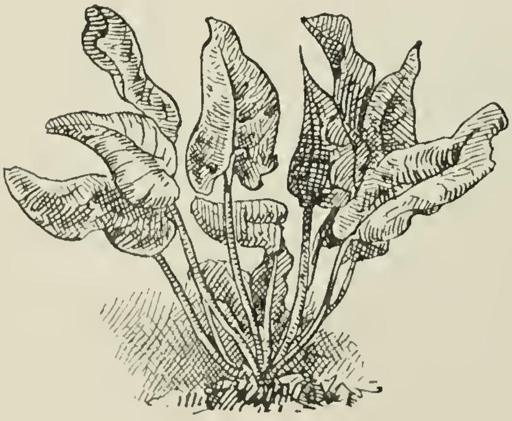

Fig. 43.—Common Beet.

(indiarubber) and the opium of commerce are simply the dried juices of two world-known plants; caoutchouc being obtained from *Hevea brasiliensis*, a tall tree of tropical America, and opium from our large garden Poppy (*Papaver somniferum*).

Professor Kerner relates some curious facts to illustrate the protective purposes of the milky juices of plants. These protective juices are not, as in the case of the acid juices already referred to, required to keep off birds and mammals, but to shield the plants, and particularly the floral organs of plants, from the depredations of ants and other insects. Kerner's observations, recorded in his *Flowers and their Unbidden Guests*, were confined to two species of the Lettuce family—*Lactuca angustana* and the Common Lettuce (*L. sativa*); and he thus describes the effects of the flow of juice on some ants whose little hooked feet had cut through the epidermis of the plants in certain places and thus induced the flow: "Not only the feet of the ants, but the hinder parts of their bodies were soon bedrabbled with the white fluid; and if the ants, as was frequently the case, bit into the tissue of the epiderm in self-defence, their organs of mastication also at once became coated over with the milky juice. By this the ants were much impeded in their movements, and in order to rid themselves of the annoyance to which they were subject, drew their feet through their mouths, and tried also to clear the hinder part of their body from the juice with which it was smeared. The movements, however, which accompanied these efforts simply resulted in the production of new fissures in the epiderm, and fresh discharges of milky juice, so that the position of the ants became each moment worse and worse. Many of them now tried to escape by getting, as best they might, to the edge of the leaf, and letting themselves fall from thence to the ground. Some succeeded, but others tried this method to escape too late; for the air soon hardened the milky juice into a tough brown substance, and after this all the

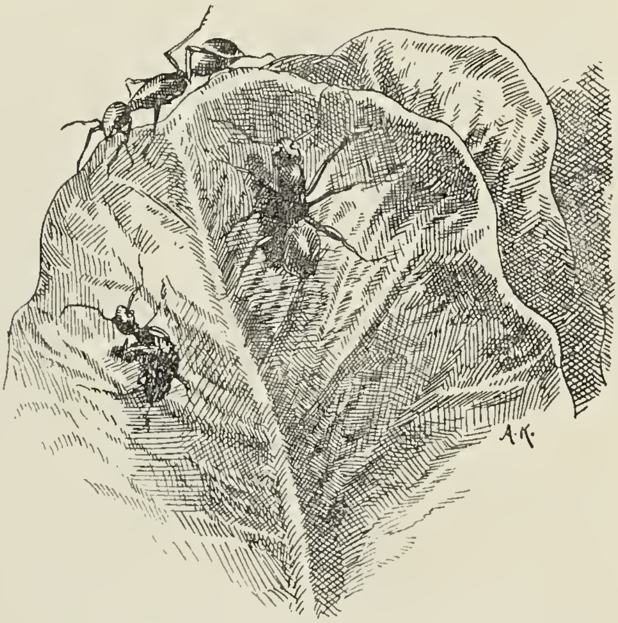

Fig. 44.—Ants held fast by the milk-sap of the Common Lettuce.

strugglings of the ants to free themselves from the viscid matter were in vain. Their movements became gradually fewer and weaker, until finally they ceased altogether."

Latex-yielding plants increase in number as we approach the tropics. The milk-sap is in some cases extremely nutritious; in others, poisonous in the highest degree. The juice of one species of Euphorbia (*E. balsamifera*), thickened into a jelly, is eaten as a delicacy by the inhabitants of the Canary Islands; and the Singhalese use the latex of the Ceylon Cow-tree (*Gymnema lactiferum*) exactly as we do milk—a fact which perhaps accounts for what Miss Gordon Cumming calls their "invincible objection to cow's milk." * The South Americans have their Cow-tree also (*Galactodendron utile*), a native of Venezuela, where it forms large forests. If a tolerably large incision be made in the trunk of one of these trees, it will yield a quantity of rich sweet milk, sufficient to satisfy the hunger of several persons. "What most interested us" (in the virgin forest near Pará), says Dr. Wallace in his *Travels on the Amazon*, "were several large logs of the Milk-tree. On our way through the forest we had seen some trunks much notched by persons who had been extracting the milk. It is one of the noblest trees of the forest, rising with a straight stem to an enormous height. The timber is very hard, fine grained, and durable; and is valuable for works which are much exposed to the weather. The fruit is eatable and very good, the size of a small apple and full of a rich and very juicy pulp. But strangest of all is the vegetable milk, which exudes in abundance when the bark is cut. It has about the consistence of thick cream, and but for a very slight peculiar taste could scarcely be distinguished from the genuine product of the cow." Some notches having been cut in the bark of one of these trees with an axe, "in a minute the rich sap was running out in great quantities. It was collected in a basin, diluted with water, strained, and brought up at tea-time and at breakfast next morning. The peculiar flavour of the milk seemed rather to improve the quality of the tea, and gave it as good a colour as rich cream; in coffee it is equally good."

Travellers would doubtless be thankful if the milk-saps of all plants were as nutritious as the milk-sap of the American Cow-tree; but it has been otherwise ordained. Some, as we have already remarked, are extremely injurious. The latex of the famous Javan Upas-tree (*Antiaris toxicaria*) is a deadly poison, and will produce large blisters and painful ulcers on the person who incautiously touches it. In the juice of the Mandioc-root (*Manihot utilissima*)—from which the tapioca of our shops is prepared—the Indian of Guiana dips his arrows to poison them; and the juice of a South African Spurge (*Euphorbia Caput-Medusæ*) is used by the natives of Bechuanaland for the same purpose.

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* "This prejudice has been in a measure conquered in the immediate neighbourhood of towns where foreigners require a regular supply; but (like the Chinese) no Singhalese man, woman, or child seems ever to drink cow's milk, though a little is occasionally used in the form of curds and eaten with *ghee*, which is a sort of rancid butter."—*Two Happy Years in Ceylon*, by C. F. Gordon Cumming, vol. i. p. 113.

Sugar, inulin, and starch are largely used by the protoplasm in the formation of cellulose for the cell-walls in young plants; as are also the fixed or fatty oils—olive, rape, poppy, palm, etc. (see p. 40)—which swim in the cell-sap in the form of minute, shining yellow globules. These plastic substances—all originating in protoplasm—are stored up as reserve material in the cells of seeds, bulbs, etc., though each has to undergo various changes before the final conversion into cellulose is effected. Chief among these changes is their transformation into the soluble substance *glucose*, or grape-sugar, already mentioned (pp. 32 and 36), which is conveyed through certain conducting cells to that part of the plant where new cells are being formed. How admirable is the wisdom directing this complicated process! Had the glucose been deposited in the first instance, it must have undergone fermentation, and thus would have become worthless before the plant was ready to make use of it; but the deposition of starch (or its equivalent), which can remain unchanged for almost any length of time, and which can at any moment be converted into sugar, secures the desired object in the most effectual manner.

The process is known as *metabolism* (Greek *metabolē*, a changing)—a term which is very comprehensive. It includes, indeed, not only all the chemical changes which take place in the protoplasm, but the resulting phenomena as well. Thus the substances known as *secondary* or *by-products*, such as volatile oils, resin, tannin, pectin, acids, wax, etc., are results of metabolism; so, too, are the substances called *degradation* products, which are formed by the breaking down and partial dissolving of organised structures. To this class belong the mucilage of quince-seeds and linseed, and many kinds of gum, in some of which—as the Gum Tragacanth—the organisation of the cell-walls used in their formation may be detected. The gum named is obtained from the Great Goat's-thorn (*Astragalus Tragacantha*), a Levantine shrub, from the bark of which it exudes spontaneously at certain seasons of the year, when it coagulates and hardens and is then ready to be collected.

How marvellous are these changes when considered as the results of protoplasmic activity! What miracle-workers are our little protoplasts! What a box of wonders is every living cell! "They may be regarded," as Dr. Taylor pleasantly remarks, "as so many organic chemical laboratories, in which synthesis is carried on even more vigorously than analysis. Some are starch manufacturers like Colman, as in the potato and other tubers and bulbs; some are perfume distillers like Rimmel, as the cells in the leaves of the Sweet-briar (*Rosa rubiginosa*), Lavender (*Lavandula*), and Mints (*Mentha*). Every cluster of cells has a work to do—sometimes special kinds of work, but usually generalised kinds."

We would remark, further, that the reserve materials which we have been considering (not the degradation and by-products, but the nutritious substances) fall naturally into two great divisions. The first division comprises those substances which, like protoplasm, contain the elements carbon, hydrogen, oxygen, nitrogen, sulphur, and perhaps, in some cases, phosphorus. They are *essentially* the plastic materials out of which the protoplasm produces its wonderful transformations. Hence the name *proteids* has been bestowed upon them, from Proteus, the fabulous old man of the sea, who possessed the remarkable power of changing his form. The substances comprised under the second division are distinguished from proteids by the absence of nitrogen and sulphur, whence they are frequently called the *non-nitrogenous compounds*.

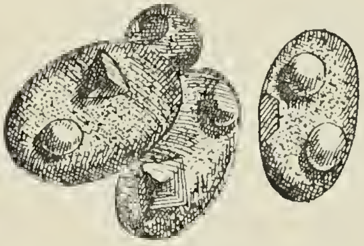
Fig. 45.—Crystalloids and globoids in aleurone-grains.

The proteids include such substances as *gluten*, which forms a great part of the corn-grains, and which is identical in its composition with albumen, the basis of animal tissues; *legumin*, which exists largely in the pea and bean; and *aleurone-grains*, which are abundant in oily seeds, and which almost always enclose other bodies—namely, crystalloids and globoids (fig. 45). The non-nitrogenous compounds, which invariably contain the elements carbon, hydrogen, and oxygen, are starch, sugars, inulin, and fatty oils.

A word as to the *fixed* or *fatty oils*. One of the most valuable of these is olive oil, which is obtained from the Wild Olive (*Olea europea*), a shrubby tree cultivated with great care in Spain, Italy, Syria, and other countries on the shores of the Mediterranean Sea. The oil is contained in the drupe (fig. 46). Palm-oil is obtained from the fruit of various Palms, and approaches to the condition of ordinary fat; so that it is well adapted for the manufacture of candles. It constitutes an important article of food in those countries where Palms abound. The Flax-plant (*Linum*) yields the valuable linseed-oil, which is expressed from the seeds and largely used after distillation in the preparation of paint. The pressed seeds from which the oil

Fig. 46.—Section through the fleshy portion of a berry of Wild Olive, showing the stony centre.

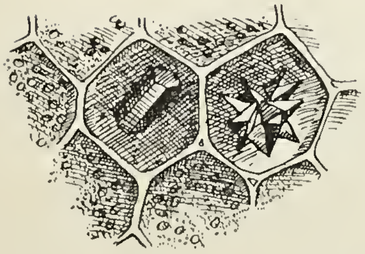

Fig. 47.—Crystals in cells of Onion (*Allium*).

has been partly extracted constitute the oil-cake often given to cattle on account of its fattening properties. Rape-oil is extracted from the seeds of the Rape-plant (*Brassica Napus*), and is the oil best adapted for the lubricating of machinery; while the seeds of a species of Poppy (*Papaver somniferum*) supply the oil of that name; and those of the monkey-nut (*Arachis hypogea*) yield the well-known ground-nut-oil, which is largely used in India, Java, and Malacca both for lighting purposes and for food. The fatty oils may be coloured black with osmic acid, or pink by alkanna, and are soluble in ether.

Crystalloids, to which reference was made a paragraph or so back, must not be confounded with true crystals. They resemble them in appearance, but are essentially different, being capable of swelling up when treated with certain reagents, which true crystals are not. They are to be met with in most oily seeds, as the seeds of the Castor-Oil-plant (*Ricinus communis*), and are not uncommon in the tuber of the potato. In the latter they take a cubical form, and on being immersed in water split up like a pack of cards, without dissolving (fig. 45).

True *crystals* (fig. 47) are far more plentiful in vegetable tissues than crystalloids; for which reason they call for more extended notice. Plants of the Cactus tribe (*Cactaceæ*, fig. 48) usually contain a great quantity of oxalic acid, which would be deadly to the plants were it not that they take up from the soil a proportionate quantity of lime; and this combines with the acids in insoluble

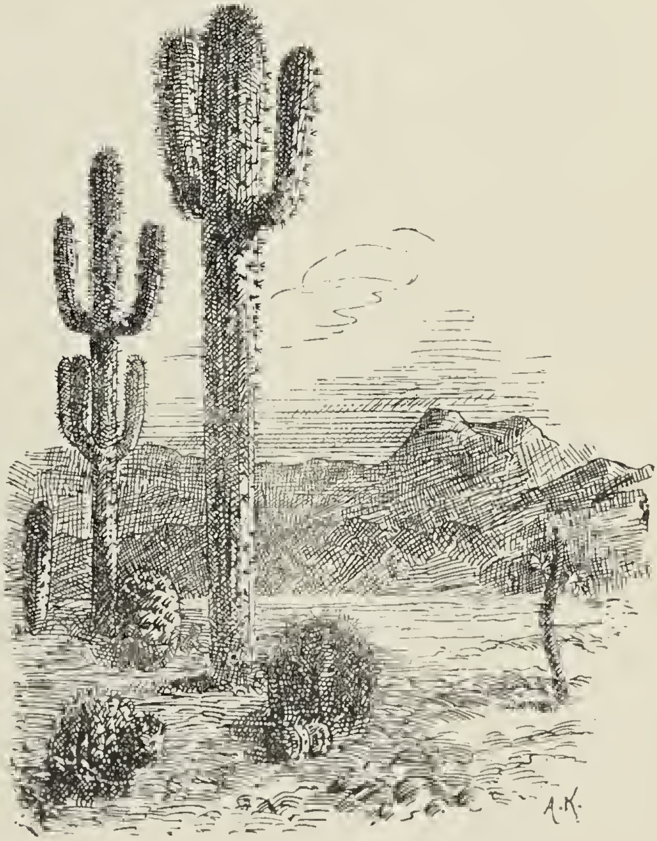

Fig. 48.—Some South American Cactuses.

crystals. The Old-Man Cactus (*Cactus senilis*) is computed to contain as much as 85 per cent. of oxalate of lime; and it often happens with certain species of this tribe that their tissues become so loaded with crystals as to render the plants quite brittle. Dr. Carpenter, in his work on the microscope, relates that when some specimens of *Cactus senilis*, said to be a thousand years old, were sent to Kew Gardens from South America some half-century ago, "it was found necessary for their preservation during transit to pack them in cotton like jewellery," so fragile were they from the quantity of crystallised acid in their tissues.

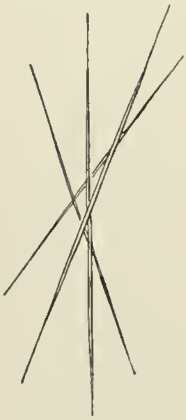
Fig. 49.—Raphides of a species of Fuchsia.

Plant crystals are always formed of oxalate of lime or potash. The lime enters the plant as sulphate of lime, and when the sulphur—afterwards used by the protoplasm in the manufacture of new proteids (p. 40)—has been separated by the protoplasts, the lime combines with the oxalic acid already in the plant, and crystallisation takes place. The crystallised acid has much the appearance of Epsom salts, but it is highly poisonous.

Never speak of the formation of crystals as "growth." This has sometimes been done, even by writers of considerable reputation, but it is a mistake. Only living matter can be truly said to grow; and crystals are not living matter. The processes of crystal formation are entirely different from the wonderful and all but miraculous life processes of protoplasm. The first are purely chemical in their nature, and may be successfully imitated in the laboratory; the second are vital rather than chemical, and defy imitation. A schoolboy may be taught to make crystals; the most skilful chemist cannot make a grain's-weight of living matter. "The processes are absolutely distinct," says Professor Beale, "and the 'growth' of living things implies Life, and such growth never occurs in the absence of Life."

True crystals are found in the epidermal cells of the leaf of the *Iris* and the *Fuchsia*. In the latter, they are disposed in little bundles, and look like so many broken pieces of needle—whence the name *raphides* (Lat. *raphis*, a needle) which is sometimes applied to them (fig. 49). Stellate crystals are met with in the bark of the Lime-tree (*Tilia*); cubical in the Onion (*Allium*); and sphere crystals in one of the Stinkhorn Fungi—viz., *Phallus caninus*. A good slide for showing the cubical crystals of the Onion may be made by soaking a little of the brown skin of the bulb in turpentine till it is quite clear, and then mounting in balsam. In Switzerland, oxalate of potash is prepared from the leaves of the Common and Wood Sorrels (*Oxalis acetosa* and *Acetosella*), so plentiful are the crystals in their tissues.

The cell-walls of the epidermis of some plants of the great Nettle order (*Urticaceæ*) and a few others increase in thickness in a very peculiar manner, the deposit taking the form of bladder-like growths containing carbonate of lime. The cells of the Indiarubber-plant (*Ficus elastica*) and Common Walnut-tree (*Juglans regia*) show these remarkable ingrowths very distinctly (figs. 50 and 51). They have been christened *cystoliths* by the learned, a name derived from the Greek *kustis*, a bag or bladder, and *lithos*, a stone. Minute punctiform cystoliths, which reflect the light, are the cause of the white spots on the downy leaves of those curious shrubby plants, the Boehmeria, a tropical genius of the Nettle order.

Closely allied with crystals are certain by-products of a more adventitious kind known as "vegetable stones." A large proportion of these are formed and deposited in the tissues from the siliceous and calcareous substances which circulate with the sap. Thus, in the Bamboo, a round stone is found at the joints of the cane, called "tabasheer"; and in Java and other East India islands, round and pear-shaped stones of carbonate of lime are sometimes found in the endosperm (the edible albuminous part) of the coco-nut. In appearance they are almost lustreless, and not unlike a white pearl. They are often as large as cherries and as hard as felspar. The natives of the Celebes put high value on these vegetable opals, using them as amulets and charms against disease.

Among the other substances which come under the category of by-products may be mentioned the *volatile* and *aromatic oils*, so useful in medicine and perfumery. Of these our naturalised and British plants supply not a few, as every one knows who is acquainted with such old favourites as Lavender and Rosemary, Spearmint and Peppermint, Thyme and Marjoram, which all yield aromatic oils. Yet we must turn to hotter countries for the perfumes most prized and coveted, and especially to the intertropical regions. Thus Turkey (chiefly the Roumelian provinces), Persia, and the Rajpootana States supply the fragrant attar-of-roses, which is obtained by distillation from the petals of that flower. The quantity of rose-leaves

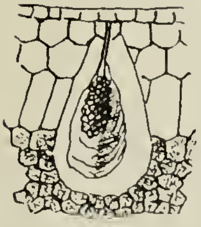

Fig. 50.—Cystolith from leaf of Indiarubber-plant.

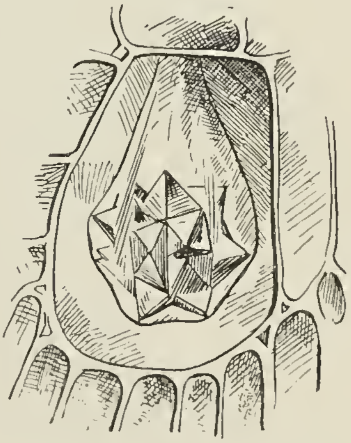

Fig. 51.—Crystals (a cystolith) from cell of Walnut-tree.

required to furnish a teaspoonful of this princely perfume is almost fabulous, and sufficiently accounts for the high price which the oil commands. The London market is chiefly supplied from Roumelia, whose average annual output is from thirty to forty hundredweight, valued at about £60,000.* The Turkish attar is usually adulterated either with the oil of *Geranium* or of the Indian Khus-khus Grass (*Andropogon*). There are two other kinds of attar, both of Indian extraction—namely, the Jasmine and Keova, the former being a production of the Large-flowered Jasmine (*Jasminum grandiflorum*), and the latter of the fragrant flowers of the Screw-pine (*Pandanus odoratissimus*). Then we have oil of cloves and of cinnamon, of cumin and of camphor, of lemons and of bitter almonds, of turpentine and eucalyptus—all aromatic oils of more or less value; while the peculiar scent and great durability of russian leather is attributed to the employment, during the process of tanning, of a volatile oil obtained by the distillation of Birch bark (*Betula*). The oil has a brown or black colour, and a little of it poured on paper and allowed to dry gives to the paper the scent peculiar to Russian leather. On a future occasion, when the odours of flowers in relation to insects will be our subject, allusion will be made to Kerner's helpful classification of the aromatic oils, and some further light will be thrown on this very interesting subject.

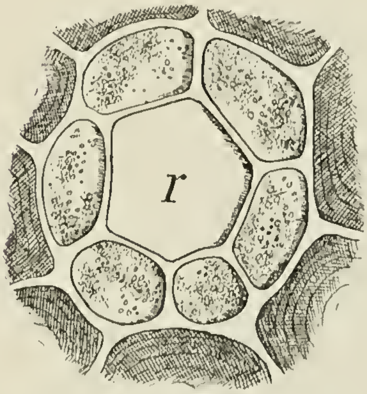

Fig. 52.—Transverse section through resin-passage (*r*) of Scotch Fir.

We may add that the oil of Birch bark mentioned above is simply a form of *tannin*, which is one of the most widely distributed of secondary products. Its characteristic reaction is that of forming insoluble compounds with gelatine, solid muscular fibre, skin, etc., which then acquires the property of resisting putrefaction, as in the tanning of leather. Kerner has pointed out that its extremely bitter taste protects the branches, cortex, and fruits from being eaten. The plants which furnish most of the tannin of commerce are the Oak (chiefly *Quercus sessifolia*, *infectoria*, and *pedunculata*), Hemlock Spruce (*Abies canadensis*), Red Pine (*Pinus contorta*) and Water-smartweed (*Polygonum amphibium*). Other by-products of metabolism—and the last that we shall here speak of—are *resins*, *waxes*, and *balsams*, which naturally fall into one group.

Young buds are often coated with a balsam (*i.e.*, a solution of resin in an ethereal oil) to protect them from cold and wet during the winter and early spring. The Horse-chestnut (*Æsculus Hippocastanum*) and Balsam Poplar (*Populus balsamifera*) offer familiar examples of these varnished buds. Again, the stems of many plants of the Clove order (*Caryophyllaceæ*) are plentifully supplied with a sticky solution formed of resin and gum, which effectually forbids the approach of insects to the flower along that route; while resin-ducts are largely present in trees of the Terebinth and Cone-bearing orders (*Anacardiaceæ* and *Coniferæ*). The resin-producing capabilities of the Pine family are, indeed, phenomenal, one and a half or even two pounds being frequently obtained from a single tree at each quinquennial tapping (fig. 52). The Maritime Pine (*Pinus Pinaster*) is perhaps the most prolific of all. It begins to yield abundantly when twenty-five or thirty years old, and when the process is well managed will continue to yield for a very long time. There are Pines at La Teste, in France, with as many as sixty scars of places where they have been tapped, evidence that the working of these trees goes back at least two centuries.

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* It is said that 100,000 roses only yield 180 grains of attar!

Wax is another frequent vegetable production, especially in the torrid zone, where many of the wax-bearing plants supply the natives with light. This substance gives the bloom to the plum, cherry, and grape; and "the raindrops lie on the waxy surface of the Cabbage-leaf like balls of diamond, from the total reflection of light at their points of contact." Wax is secreted in the cuticle for the purpose of getting rid as rapidly as possible of the water which is deposited on the surfaces of the leaves, or to prevent excessive loss of water by transpiration—the latter an invaluable provision in the Aloe (fig. 53), Cactus, and other fleshy leaved plants inhabiting the hot, parched regions of the tropics. A further use is noticed by Kerner. He tells us that the branches of many Willows which bear honey-laden flower catkins are provided with wax-like coverings (combinations

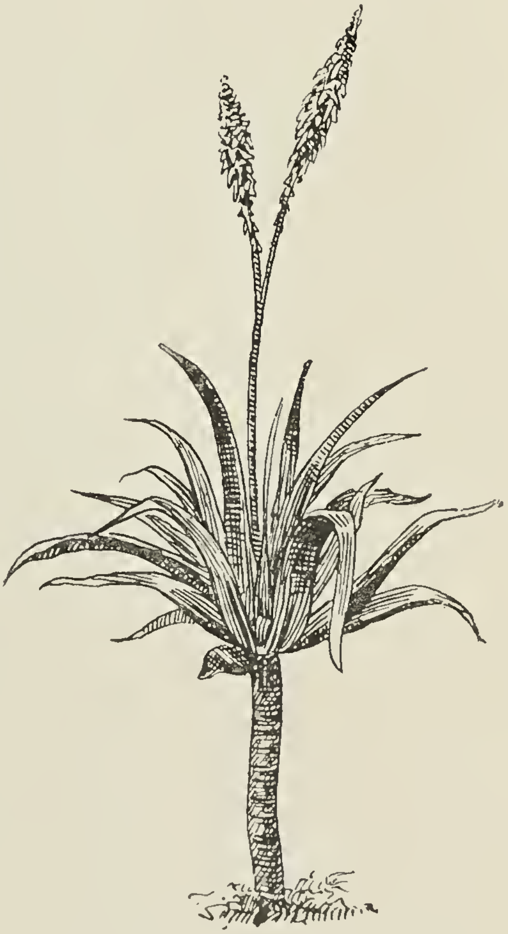


Fig. 53.—An Aloe (*Aloe vera*).

of fatty acids with glycerine), so extremely smooth and slippery that would-be visitors to the flowers (unserviceable honey-thieving ants for the most part) strive in vain to accomplish the ascent.

The delicate waxen bloom of many plants presents some curious forms under the microscope. The bloom on the Rye, familiarised in a popular song, consists of dense agglomerations of rods or needles, and is a most interesting object for examination. So, too, is the wax coating of the leaves of the Banana (*Musa*), which consists of little rods that stand erect on the cuticle like so many Liliputian posts; while the "frosting" of the leaves of many Lilies is made up of tiny granules of wax.

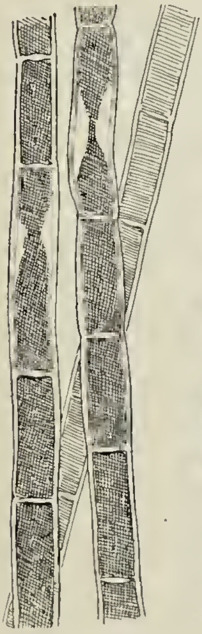
It is worthy of remark how much the production of these and other secretions depends upon the intensity of light and heat. Plants that will *grow* well enough in a climate very different from that to which they have been accustomed, will, nevertheless, frequently cease to form their peculiar secretions, or at least produce them in very diminished quantities. This accounts for the fact that the Tobacco grown in this country is so vastly inferior to that grown, say, in Cuba or Persia; and to the same cause may be traced the great scarcity in English-grown roses of the fragrant attar already spoken of, which is comparatively abundant in the flowers cultivated for that product in India, Persia, and Roumelia. The scent of Lavender, remarkably enough, is more powerful in British-grown plants than in those cultivated in the south of Europe, its native habitat, much light and heat being unfavourable to the production of the fragrant oil. Equally curious is the statement—the truth of which is vouched for by Dr. Christison—that the Cowbane (*Cicuta virosa*) and Hemlock Water-dropwort (*Œnanthe crocata*), which are poisonous in most districts of England, are innocuous when grown near Edinburgh! The statement seems hardly credible, and though supported by so high an authority as Dr. Christison, should be received—if received at all—with considerable caution.

CHAPTER III

CELL COMMUNITIES: A CHAPTER ON TISSUES

Cell joined to cell, mysterious Life passed on
By viscous threads; selecting in its course,
From formless matter, with mysterious touch
That seems a prescience, and that never errs,
Materials diverse, out of which to weave
The warp and woof of tissues.

EVERY plant, as already mentioned, consists either of a cell or cells, or of the products of their formation and transformation. When a Rose-tree begins to grow, its growth is not effected merely—nor chiefly—by the increase in size of already existing cells, but by the formation of cells entirely new; and this is true of all multicellular plants. Of course, *cell multiplication* (as it is called) also takes place in unicellular plants. This we saw to be the case with *Sphærella pluvialis*; but in such instances the new cells become distinct individuals; they cease to form part of the parent plant, and enter upon an entirely independent existence.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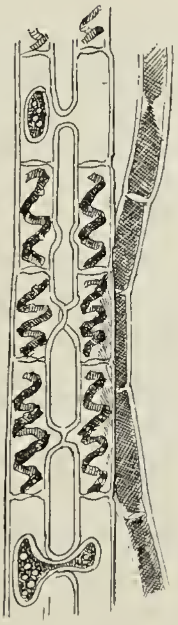
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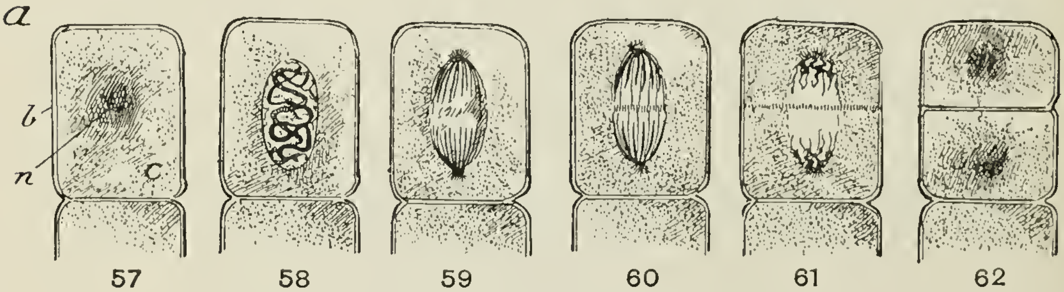
Fig. 54.—Silkweed or Crow-silk. Portions of the filaments of three separate plants. Fig. 55.—The same: portions of the filaments of three other plants, of which ten of the cells are seen to be in various stages of conjugation.

Fig. 56.—A row of cells (diagrammatic).

Now cells may multiply in four ways. *Free cell formation* is one of these; and we take this mode of increase first, because it is the means by which both the resting and zoospores of *Sphærella* are produced. The pollen-grains of most Flowering Plants are formed in this way, as well as many zoospores besides those of *Sphærella*. The process has been already described at some length (pp. 11 and 12), and there is no need to go over the ground again.

Sometimes, however, the entire protoplasm of the parent cell, instead of dividing off into several individuals, is used up in the formation of a *single* new cell. This mode of cell formation, which is like a renewing of the youth of the individual, is appropriately termed *rejuvenescence.*

In a few forms of vegetable life the protoplasm of two or more cells coalesces for the purpose of reproduction, and this is known as *conjugation.* Here (figs. 54 and 55) are some cells of a little fresh-water weed, *Zygnema quinium*, common enough in our ponds and ditches, and popularly known as Silkweed or Crow-silk. Each of the pale yellow-green filaments represents a separate plant, and is built up of a single row of cells; but when conjugation is about to commence, the cell-walls of two distinct filaments that happen to float in proximity form blunt projections from their sides, and reach out to one another till they meet. Then, at the points of contact, those portions of the walls which hinder communication between contiguous cells dissolve away; the sap at once occupies the passage thus formed; and the protoplasm from one of each pair of united cells, forcing its way through the narrow channel, fuses with the protoplasm in the companion cell, and so conjugation is effected.



Figs. 57–62.—Indirect nuclear division (*vide* text).

But a far more common method of increase than any which we have yet considered is that which is known as *cell division.* Increase *in length* of every filamentary plant of Silk-weed was due to cell division; the cells of the fragment of Onion-skin which we were speaking of in the previous chapter multiplied in this way; so did the star-shaped cells of the Common Bean lately mentioned. Indeed, the vegetative organs of most plants (as distinguished from the reproductive organs) are almost always so formed.

But what is cell division? To say that all normal vegetable growth takes place by such means is no explanation of the process: we are only moving in a circle. Will you follow an attempt to illustrate the process by means of a few diagrams? We will suppose that the first sketch (fig. 56) represents a row—or part of a row—of vegetative cells, of which the uppermost (*a*) is about to divide. Here is this cell on a larger scale (fig. 57), with its cell-wall (*b*) and its granular protoplasmic contents (*c*), in the midst of which is drawn a circular disc to represent the nucleus (*n*). Changes in the nucleus intimate that the process has commenced. The nucleus elongates, and its delicate *fibrillæ*—delicate even under the highest powers of the microscope—appear at this stage to interlace in a confusing manner (fig. 58). A little later the tanglement is over, and the *fibrillæ* are seen to be converging to one or the other of the poles of the nucleus (fig. 59). Between these *fibrillæ* new and yet finer threads presently appear, each of which extends from pole to pole, the figure now presented to the eye being that of a miniature spindle in the midst of the protoplasm (fig. 60), and this spindle becomes more and more extended till it stretches across the cell. Meanwhile, along the fibres stream granules of protoplasm, which, gathering where the spindle is widest (*i.e.*, exactly midway between the poles), unite to form a plate (fig. 61); while the specks of congested protoplasm which constitute the ends of the spindle become distinct and perfect nuclei. From the plate thus formed is developed in time a wall of cellulose, by which the entire cavity of the mother-cell is divided into two chambers; and then, with the disappearance of the *fibrillæ*, the nuclei finally part company, and cell division is accomplished (fig. 62).

Such, then, are the principal means of cell multiplication—free-cell formation, rejuvenescence, conjugation, and cell division; and this leads us to another important subject—that of *cell fusion*—with which we may link what little there is to say about vegetable tissues, and then close this division of our subject.

Any set of similar cells, governed by a common law of growth, forms a *tissue*; and two or more cells, coalescing into a single individual by the partial or entire breaking down of their dividing walls, form a *vessel*. The latter process is cell fusion. We have seen an example of tissue already in the stellate cells of the Bean (fig. 20); the fragment of Onion-skin shown in fig. 14 was another example. The diagram now given (fig. 63) offers examples both of vessels and tissues. *C*, *f*, and *g* are vessels, *a* and *h* are tissues of cells. The darkly shaded portion at *b* is woody fibre, of which we shall speak again in a moment. The subject need present no difficulties, as the ground has been already cleared by the remarks upon cell forms and structure; but we trust the reader will follow the description closely, as the points to be touched upon are of great importance. We will consider vessels first.

To this end it may be well to take a backward glance for a moment. On pp. 25, 27, and 28 are illustrations of the spiral, annular, reticulated, and pitted cells (figs. 26, 30, 31, and 32). Now from all of these, vessels may be formed. Place a lot of spiral cells on top of one another, and break away the whole or greater part of each of the partition walls, and you will have a *spiral vessel* (fig. 63, *f*). Do the same with a number of annular cells, or reticulated cells, or pitted cells, and you will have *annular vessels*, or *reticulated vessels*, or *pitted vessels*, as the case may be (fig. 63, *c* and *g*). Of course this could not be done in reality, the vessels being far too small; but we use popular language. Hooke estimated that a cubic inch of oak contains upwards of seven millions of vessels; and another of the old microscopists, Leuwenhoek, computed that the bole of an Oak, only four inches in diameter, contains about two hundred millions! We are not sure whether Damory's Oak in Dorsetshire is still standing; but this tree not many years ago measured eighty-four feet in circumference, and it was then shown by a laborious calculation that more than 240 millions of miles of vessels were packed in a single foot's length of the stem, and that if the vessels contained in the whole tree could be placed end to end in a single line, they would have made a communication backwards and forwards between the sun and every planet in the system! The two or three thousand miles of piping which underlie London look rather paltry in comparison with this.

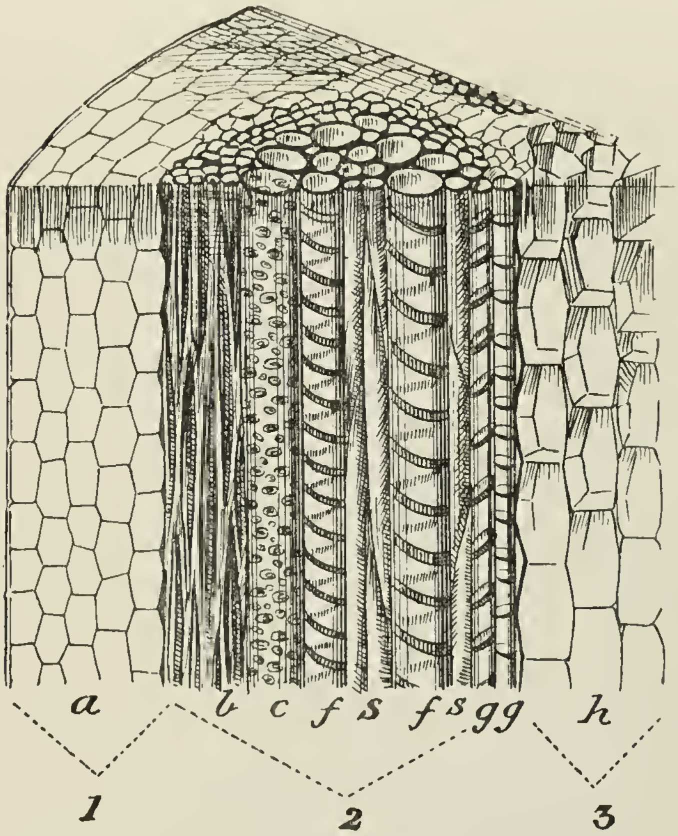


Fig. 63.—Portion of stem of Italian Reed (Diagrammatic). 1. Outer covering of the stem or integument. 2. Fibro-vascular bundle. 3. Medulla or pith. (*a*) Tissue of cells (parenchyma); (*b*) Bast-fibres; (*c*) Pitted vessel; (*f*) Spiral vessels; (*g*) Annular vessels; (*h*) Soft loose cells of pith; (*s*) Sieve-tubes or bast-vessels.

In certain cells of the Ferns and their allies the thickening deposit laid down on the inner surface of the cell-walls takes the form of miniature ladders, on which account the vessels constructed out of these cells (though absorption of transverse septa is rare in Ferns) are called *scalariform*, or ladder-like (Lat. *scala*, a ladder). As a matter of fact, scalariform vessels are only modifications of the reticulated form, from which they differ by the partition-walls of secondary deposit being larger and more regular.

Spiral and annular vessels occur in the stems of most Dicotyledons (plants with two seed-leaves), but only in what are known as the primary wood, which forms the first circle round the pith (*vide* Chapter VII.), and is called on that account the *medullary sheath* (Lat. *medulla*, the marrow of bones); whereas reticulated and pitted vessels are found in the denser internal parts of the woody layers (*vide* Chapter VII.). All of these occur in the leaf-stalks and veins of leaves, and in certain parts of the flower, but never in the bark. They keep the cellular tissue of the leaves stretched and extended, acting like the ribs of an umbrella. In Monocotyledons (plants with only one seed-leaf), they are placed in the interior of the woody bundles of the stem, and sometimes you will meet with them in the root-fibres. In the mature state they contain nothing but air; but occasionally, in the spring, a portion of the sap sucked up by the roots is pressed into them—a process on which depends, for example, the "weeping" of wounded grape-vines (Thomé's *Lehrbuch*, p. 30).

There is one other kind of elongated cell found in the woody parts (fibro-vascular bundles) of many plants which should not be passed over. We have described it as "woody fibre," but the scientific name for these vessels is *bast-tubes* or *bast-fibres* (fig. 63, *b*). Bast-tubes must not be confounded with what are known as *sieve-tubes* or *bast-vessels*. The former are long, pointed, and thick-walled, and occasionally, though very seldom, they are branched. The sieve-tubes or bast-vessels, on the other hand, consist of slender flexible tubes, with their walls unmarked by secondary deposit (fig. 63, *s*). The dividing walls of the cells out of which the last-named vessels are built are not entirely absorbed, as are the partition-walls in the bast-fibres; but they are perforated in various places so as to resemble a sieve, whence they are called *sieve-plates*, and the vessels, as we have seen, *sieve-tubes*. Not infrequently the side walls of adjoining tubes are also perforated.

If two or three hollow cylinders, covered at each end with parchment, be placed together lengthwise, and holes be driven through the parchment covers so that the cylinders freely communicate with each other, a very fair idea will be gained of a sieve-tube: the perforated parchment covers will, of course, answer to the sieve-plates. These vessels retain their protoplasm, which circulates through the sieve-plates, and they evidently play an important part in the life history of the plant. The German physiologist, Sachs, was of opinion that much of the new protoplasm is produced in the sieve-tube, and this view is shared by Professor Thomé and other eminent botanists. These also are the vessels which play so important a part in the diffusion of the sugar formed by the chloroplasts in the leaves of plants.

In the leaves and outer bark of many plants, thin-walled vessels of various structure may be met with, which usually run parallel with each other and invariably contain bundles of needle-shaped crystals. These are closely related to the sieve-tubes and are known as *utricular vessels.* A very large number of plants have them.*

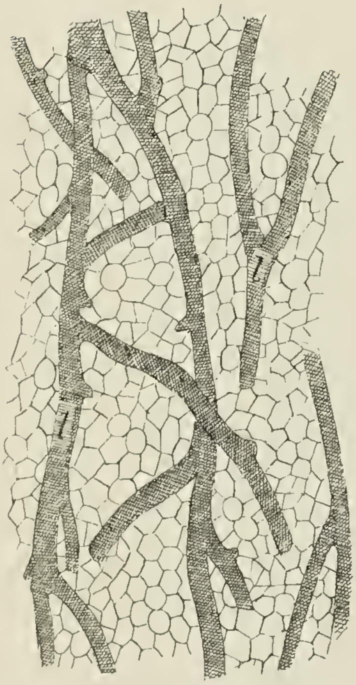


Fig. 64.—Longitudinal section of a portion of the cortical parenchyma of a Euphorbia, showing laticiferous or branched laticiferous "cell" (*l*) in the midst of the tissue.

The *laticiferous vessels*, which may next engage us, though of much interest from a physiological point of view, need not detain us long. These vessels, as their name implies, convey the milk-sap or latex to the parts of the plants which require, or, at least, *seem* to require it; for there is some doubt as to the function of latex—whether it is more than a by-product. Like the vessels last mentioned, the laticiferous vessels are closely allied to the sieve-tubes, consisting of closed tubes, cylindrical or angular in shape, and usually with thin, transparent walls. They are formed by the union of cells, but not necessarily (and here they differ from most vessels) by the union of a single row of cells. They appear to be bound by no rule of growth, so that some very irregular vessels are often seen which branch out in all directions and form a copious network, with free intercommunication. Their presence is limited, however, to a small number of plants; for the milk-sap of many latex-yielding species is not contained in vessels, but in long, branched, simple cells. The Euphorbias (fig. 64), to which the Spurges and South African Tapioca-plant belong, abound in these cells.

We come now to *tissues*. The sections figured below preclude the necessity of any very detailed descriptions. They show four kinds of

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* According to Professor Thomé (*Lehrbuch*, p. 32), they occur in most Monocotyledons, and in some Dicotyledons, being found exclusively in the outer cortex or the foliar organs.

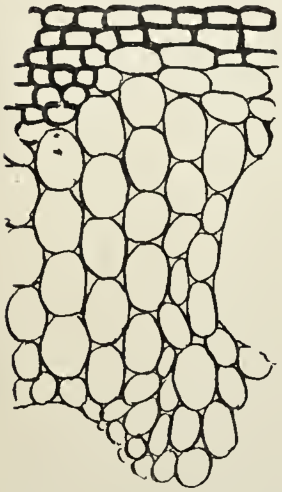

Fig. 65. — Parenchyma from the stem of the Field Horse-tail (*Equisetum arvense*).

tissue: but some courage is needed to declare their names.

The tissue of cells shown in fig. 65 is known as

Parenchyma

(Greek *parenchuma*, the spongy substance of the lungs), and this is the general name of tissues the cells of which are arranged in rows, and which are fairly equal in their dimensions, being almost as long as they are broad.

The tissue depicted in fig. 66 is distinguished as

Prosenchyma

(Greek *pros*, beside; *enchuma*, something poured or put in).* Its cells are long and tapering, and dovetail into one another, and these are the leading characteristics of prosenchyma. Yet there is no absolute dividing line between the two kinds of tissue, parenchyma passing into prosenchyma, and prosenchyma into parenchyma, by endless gradations.

The third tissue (fig. 67) has been named

Collenchyma,

a word derived from two Greek words—*kolla*, glue, and *enchuma*, a word explained above. The gluey something poured or filled in is usually most abundant in the corners of the cells, and is added by the protoplasts with the view of strengthening the delicate walls. The substance forms, one might almost say, the corner-stones of their little dwelling-houses. Collenchyma may be seen to advantage in the leaf-stalks of many Begonias, a transverse section being the best for examination.

The name of the fourth kind of tissue is as tongue-tiring as the others, but we have met with it before—

Sclerenchyma.

It will be remembered that the cells from the gritty centre of a pear (fig. 25) were sclerenchymatous cells; and it was pointed out that the name is given to thick-walled woody cells in which the protoplasm has been all used

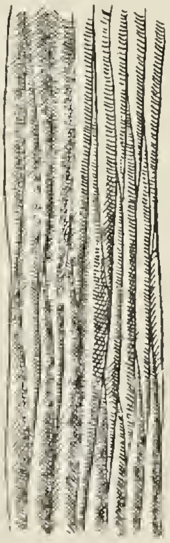

Fig. 66.—Prosenchyma of a Traveller's Joy (*Clematis Vitalba*).

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* The word was formed on the model of "parenchyma" with little regard to derivation (*Text-book of Biology*, p. 409).

up. The section of a plum-stone (fig. 68) shows the same thing. Sclerenchyma comprises, indeed, those tissues the cells of which have become much hardened by secondary deposit, and which contain no protoplasm. It performs the mechanical office of support and strength, and is emphatically *dead* tissue, the very opposite of the tissue to which we next invite attention, namely—

MERISTEM.

Meristem (Greek *meristos*, divided) is the name given to *growing* tissue the cells of which are continually dividing so as to produce fresh tissue. These actively dividing cells have thin walls, and no spaces between the cells: they are rich in protoplasm, and always contain a nucleus. From cells of this kind all permanent tissues originate. They are found, therefore, only in the growing parts of plants, as buds, the apex of roots, and in certain parts of the stem. Even sclerenchyma originated in meristem.

Special cells or groups of cells, so disposed as to form cavities in the tissue, are engaged in the formation of the degradation- and by-products (p. 39), and to these the name of *glands* has been given. Thus we have resin-glands, oil-glands, camphor-glands, honey-glands, and others that need not be particularised. They abound, for instance, in the rind of the orange and lemon, the odour and flavour of which are derived from minute drops of volatile oil stored up in vast numbers of these little cavities. Glands are frequently external organs, and may be borne upon the ends of hairs, which are then called *glandular hairs*. We find them, for example, in the Chinese Primula. The margins and upper surface of the leaves of our English Sundews (*Drosera rotundifolia* and *D. intermedia*) are provided with delicate glandular tentacles (loosely called "hairs" in many text-books), which are veritable insect-traps. The glands have the appearance of tiny dew-drops, but exude a viscid secretion, by which the thirsty and deluded visitors to the plant are caught and retained—for a purpose which will be explained in the next chapter.

The various kinds of vessels and permanent tissue may be conveniently classed under three heads, which are easily remembered, the arrangement being quite natural. If you take any ordinary leaf—say, the leaf of a Lime

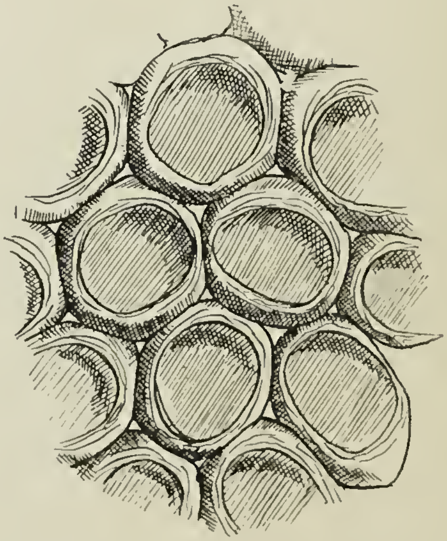

Fig. 67.—Collenchyma of the Common Sow-thistle (*Sonchus asper*).

—you will perceive that it consists of a thin outer skin, enclosing some tough net-like veins and a lot of soft tissue which fills up the spaces between the veins. The outer skin consists of a single layer of cells and is called the *epidermis* (Greek *epi*, upon, and *derma*, skin). The veins are composed in the main of bundles of vessels and long woody cells, and belong to what is called the *fibro-vascular system*; and the soft tissue which constitutes the rest of the leaf is known as *fundamental* or *ground tissue.*

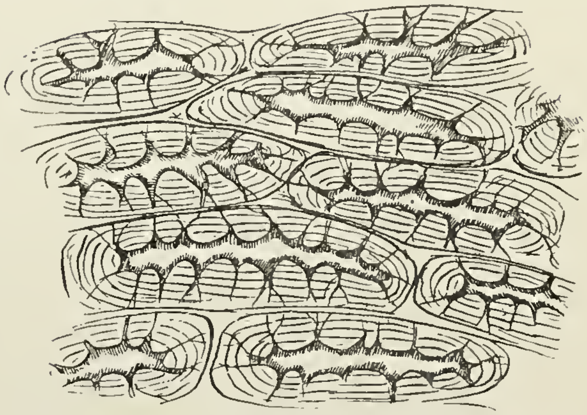

Fig. 68.—Sclerenchyma from the stone of a plum made up of lignified cells.

Here, then, we have the three great divisions under which all permanent tissues and vessels naturally fall. Let us go over them again. First, there is the epidermis, a thin cellular covering on the exterior of the plant; secondly, the fibro-vascular system, consisting chiefly of wood-cells and vessels, united in bundles, which extend from the roots to the leaves and really form the skeleton or framework of the plant; and thirdly, the fundamental or ground tissue, which occupies most of the space in the young plant and consists chiefly of parenchyma. The lower plants—that is, the *Fungi*, *Algæ*, Liverworts (*Hepaticæ*), and Lichens —have no fibro-vascular bundles, and the Mosses (*Musci*) only contain them in a very rudimentary form. Plants belonging to the Cone-bearing order (*Coniferæ*), as the Pines, Larches, Yews, and Cedars (*Pinus, Larix, Taxus, Cedrus*), have wood-cells, but no true vessels, their place being taken by *tracheides*, which are not continuously open. In the higher plants, the wood-cells of the fibro-vascular bundles serve as the channels by which the crude sap, which holds in solution the nutritious principles, is conveyed from the soil to the leaves. The vessels are charged with air.

In the leaves of Gymnospermous plants—but not exclusively confined to them—is found a particular form of tissue, known as *transfusion tissue*, which has been the subject of considerable controversy. In the leaves of Conifers and most Cycads it is nearly always found in lateral connection with the vascular bundles, in some genera outside the *phlœm*, and in others opposite the *xylem*. The highly developed network of conducting tissue so prominent in the leaves of Dicotyledons is entirely absent from those of the Gymnosperms. "In order to compensate, therefore, for the lack of an efficient conducting system in the leaf, recourse has been had to the development of these peculiar tracheides (often accompanied by bast-cells of similar shape), now known as 'transfusion tissue.'"*

Here we conclude. We have travelled together over a good deal of ground, and the physiological facts which have come before us must have convinced the reader that plants are very wonderful as well as very complex organisms. We claim for them that they are not less wonderful than animals—man alone excepted. Every individual—at least, among the higher plants—is like a little city, athrob with life; in which a pulling down and building up is ever going on; in which there are lanes and alleys, and broadways and aqueducts, and the daintiest of little houses. In one part of the city are the starch factories; in another, the milk-shops; in another, the sugar refineries. Here is the jewellers' quarter, where the crystals are prepared; here the perfumers', where the most fragrant scents are distilled; here the varnish-makers' and colourmen's. Infinite in variety, marvellous in execution is the work that goes on; and some of the operations may be watched under the microscope. We may see the little artisans at work—may enter with more or less intelligence into what is being done; though *how* the marvellous results are produced we know not. Here, indeed, we reach the borders of the Unknown Land, which Science has never entered, and where the mysterious facts of Life lie hid. We screw on the highest powers of the microscope; but the secret remains a secret still. The things formed are plain before our eyes, and we may see them forming; we may note effects, and even the processes by which those effects are produced; but behind all is the mysterious principle called Life, and into this we may not enter. Again and again, as we watch those viscid, transparent specks of structureless matter beginning to move—as we see them throwing out their delicate strands, or rotating slowly in their cells—we ask in awe and admiration, How is this? But the question falls in vain. The little protoplasts work on, but will not answer.

* Mr. W. C. Worsdell, from whom these remarks are quoted, read a paper dealing with this subject at length before the Linnean Society in November, 1897; the paper will be found in vol. v. of the botanical *Transactions* of that Society.

CHAPTER IV

THE ASCENDING SAP

Now good digestion wait on appetite.—SHAKESPEARE.

IT has been pleasantly observed by one of our older physiologists that the economy of the plant is analogous to that of a well-regulated household. "The whole structure is composed of a number of different organs or members having different parts to perform in the general scheme; and these parts or functions are so beautifully adjusted together that, in every variety of circumstances in which the being is liable to be placed, they shall still be executed in harmony and with one common purpose. One organ pumps up the required water, another carries it, another uses it in cooking, another gets rid of the waste, another obtains the solid food, another carries the cooked provisions to all parts of the structure, another stores up the superfluity, another builds additions to the edifice, while another prepares to send out a colony furnished with supplies of food, and with everything requisite to begin life for themselves" (Carpenter). This is very true; and we propose now to treat a little of some of these interesting functions, on the discharge of which depends not only the life of the plant as a whole, but the permanence of the species.

Now, all the operations carried on in a plant are subordinate to the two great functions of *nutrition* and *reproduction*—nutrition, by means of which the life of each individual is sustained; and reproduction, which secures the continuance of the species. For the present our remarks will be confined to the former.

We may enter upon the subject at once by asking, What is the food of plants?—a question which involves the further inquiry, What are the constituents of protoplasm? For if, as we have seen, all vegetable cells originate in protoplasm, and every plant consists either of a cell or cells, or the products of their formation and transformation, it stands to reason that the elements of protoplasm must constitute a very large proportion of the food of plants. Now, the chief elements of protoplasm have been already enumerated. They are six in number—carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulphur; but in order to complete the list of nutrient substances, we must add the elements iron, calcium, potassium, magnesium, zinc, and, probably, sodium and chlorine.

Of these elements *carbon* is by far the most abundant. All the plants growing upon the face of the earth absorb it in large quantities. Their leaves take up the carbon from the atmosphere in the form of carbonic acid, and they grow and prosper. Give them air purified from carbon, such as we could thrive in, and they could not live; give them carbon dioxide with other matters, and they flourish. Our floors, our tables, the framework of the chairs on which we sit, have derived all their carbon, as the trees and plants derive theirs, from the atmosphere, which carries away what is bad for us * and at the same time good for them—what is disease to the one being health to the other. "So are we made dependent," says Faraday, "not merely upon our fellow creatures, but upon our fellow existers, all Nature being tied together by the laws that make one part conduce to the good of another." †

Carbonic acid, or carbon dioxide as it is now generally called, is present in the atmosphere in the proportion of four parts in ten thousand; so that, in every thousand cubic feet of air, we have not quite half a cubic foot of carbonic acid—a proportion somewhat startling when we remember that this is almost the sole source of supply to the entire vegetable kingdom; yet so great is the volume of atmosphere which surrounds the globe that, according to careful computations, at least three thousand million million pounds of solid carbon must be contained in it—a quantity which is probably far in excess of the weight of all the plants which exist upon the earth. Submerged plants, having no direct contact with the atmosphere, derive their carbon from the carbon dioxide dissolved in the water in which they live.

Carbonic acid is a gas consisting of two elements, *oxygen* and *carbon*, combined in the proportion of two atoms of oxygen to one of carbon (CO_2); and as the former is another of our plant elements, it is evident that carbon is not the only nutrient substance taken up by the leaves. Yet by no means all the oxygen required by the plant enters in through these organs. A large proportion is obtained from the water absorbed by the root-hairs, which, indeed, are the organs employed in conveying most of the food substances to the plant; and this taking in of inorganic nutrient matter by the root-hairs is known as *absorption*.

Then there is *hydrogen*. Oxygen combines with hydrogen in a certain proportion (H_2O) to form water; so that when the roots are drinking up water from the ground they are taking in two of the most essential elements of the plant. It is probable, however, that a good deal of the hydrogen supplied to the plant enters it in combination with nitrogen (another of the essential elements of all plants)—in fact, as ammonia (NH_3), that pungent gas which gives strength to hartshorn and smelling-salts, and which is dissolved in the water absorbed from the soil.

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* Perhaps we should be more exact in saying that it is the *absence* of oxygen, rather than the presence of CO_2, which vitiates the air from the animal point of view.

† Some interesting experiments by Professor T. D. Macdougal, of Minnesota, U.S.A., on the growth of various plants in an atmosphere devoid of CO_2, will be found in the *Journal of the Linnean Society* (Botany), vol. xxxi., 1896.

The other elemental food substances are also found in the soil, and are either dissolved by the water or by an *acid sap* excreted by the root-hairs. This sap is a very necessary provision, as some of the substances essential to vegetable life and growth are insoluble in water, and but for its timely services the great number of plants would be literally starved, and in a short time disappear from the face of the earth. The powerful action of this acid excretion may be shown by means of a simple experiment. Let the perfectly smooth surfaces of two slabs of marble be spread with sand to a depth of a quarter of an inch, and in one of the sand layers sow some seeds of mustard and cress. Place both the slabs in a fairly warm place and a good light, and water them occasionally till the plants on the seed-sown bed have grown for a short time. On cleaning off the sand from the slabs it will be found that the one which had the sand only will be as smooth as ever, while the other will be covered with minute grooves—a kind of rough etching of the root system. In other words, the root-hairs will have eaten their way into the marble, channelling out passages for themselves by means of the acid sap. This experiment will show how it is that large trees are able to sink their roots deep into the solid rock, which (a no infrequent occurrence) may be literally split to pieces by the subsequent growth of the tree's embedded roots—poor thanks to the friendly rock, after ministering thus lavishly to the plant; but such is Nature's way. Thus are favours requited, and the hand that brings the blessing gets bitten for its pains!

The nutrient substances are never taken up indiscriminately by the plant. Not least among the many marvels of plant life is the mysterious power vested in the root of selecting from the surrounding fluid the substances which it requires and rejecting others. Thus if you plant a pea and a wheat-grain together in the same soil, the former will take care to make the most of whatever of lime and its compounds the water of the soil contains; while the latter, rejecting these, will absorb for itself the silex or flinty matter. How this comes to pass we do not know, and the wisest of savants can assign no reason; but a power of selection undoubtedly exists. We are standing once more upon the borders of the Unknown Land.

From the fact itself we may learn a good deal. It is evident, for instance, that the soil which is planted year after year with the same

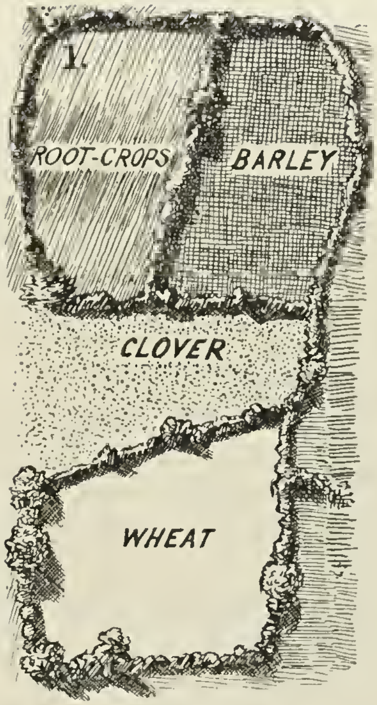

Fig. 69.—First year of Norfolk or four-course rotation of crops.

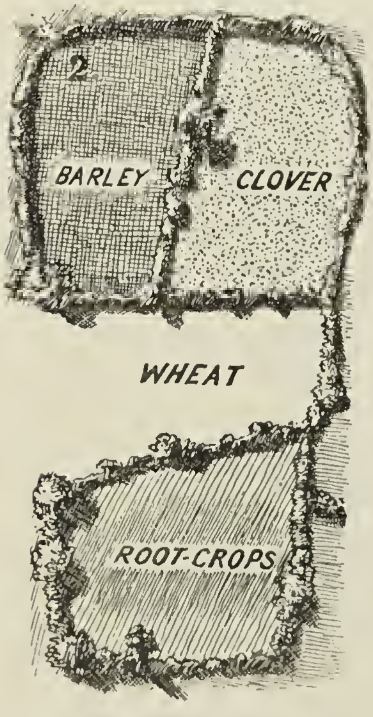

Fig. 70.—Second year of Norfolk or four-course rotation of crops.

crops will soon be impoverished, and at last become permanently unproductive for plants of that description.

> The soil must be renewed, which, often worked,
> Loses its treasure of salubrious salts
> And disappoints the roots.

A field that is sown with Wheat for a succession of years will at length lose all its flinty matter, and will then be useless, not only as a wheat-producing soil, but also for the growing of all cereal grasses and silica-containing plants.* On the other hand, the very same field may abound in nutrient substances perfectly adapted to vegetation of another kind. Farmers nowadays are well acquainted with these facts, and by a carefully selected succession of different crops—a *rotation of crops*, as it is called—and a scientific system of manuring, they provide against the otherwise inevitable exhaustion of the soil. The well-known Norfolk or four-course rotation is a case in point (figs. 69-72). This consists of root-crops, Barley (*Hordeum*), Clover (*Trifolium*), and Wheat (*Triticum*), which are dealt with in the following manner: "The farm is broken up into four portions. The first undergoes thorough tillage and is planted with Root-crops, which need especially potash and lime, and having short roots, take their food near the surface, or are surface feeders. Division 2 has Barley, which takes up very little lime and potash, but much silica, and is also a surface feeder. Clover, in division 3, takes much the same food as the root-crops, but is a subsoil feeder—that is, sends its roots deeply into the ground. The Wheat, in division 4, is also a subsoil feeder, but, like Barley, takes up much silica." Next year, and every succeeding year, the position of the crops is changed; and thus, at the end of four years, each part of the soil will have had each kind of plant growing on it, and the order for the four years will stand thus:—

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* Perhaps this statement needs a note. It has been shown that silica is not absolutely necessary for the growth of cereals; other important constituents would be exhausted long before the silica —*e.g.*, nitrogenous matter, or phosphates.

Year.	Division 1.	Division 2.	Division 3.	Division 4.
First .	Root-crops	Barley	Clover	Wheat
Second .	Barley	Clover	Wheat	Root-crops
Third .	Clover	Wheat	Root-crops	Barley
Fourth .	Wheat	Root-crops	Barley	Clover

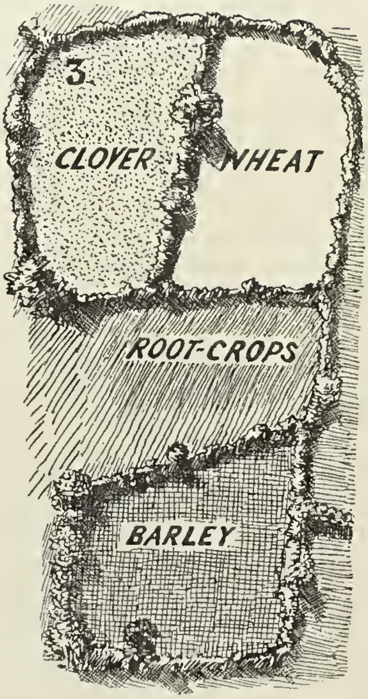

Fig. 71.—Third year of Norfolk or four-course rotation of crops.

Apropos of this subject, the great naturalist Linnæus observed a curious practice in Lapland. One part of the grains of Rye (*Secale cereale*) and two parts of the grains of Barley (*Hordeum*) being mixed together, they were sown at the proper season. The Barley shot up vigorously, ripened its ears, and was reaped; while the Rye merely went into leaf without shooting up any stem, its growth being retarded by the Barley, which may be said to have smothered it. After the Barley was reaped, the Rye advanced in growth, and, without any further care of the cultivator, yielded an abundant crop in the following year.

In former times it was a usual thing to give rest to the land by allowing it to lie fallow at certain intervals, and though our scientific agriculturists have now discovered other means of replenishing the soil, the practice has by no means died out. For thousands of years corn has been

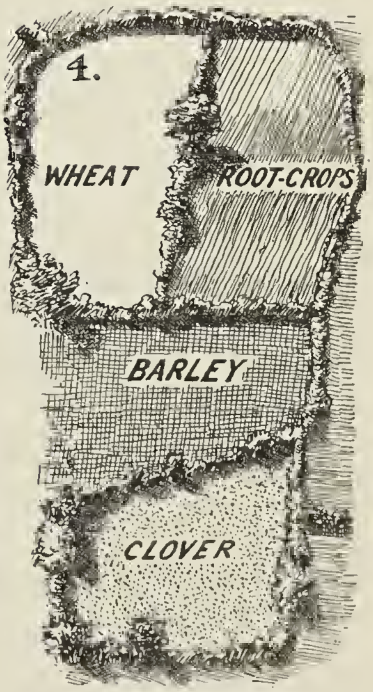

Fig. 72.—Fourth year of Norfolk or four-course rotation of crops.

grown in the neighbourhood of Mount Vesuvius, where vegetable mould is extremely scarce, by the simple method of sowing the land every third year only; while, on the other hand, many of the once prolific Wheat and Tobacco plantations of Virginia have degenerated into unproductive pasture lands, because the soil, by a contrary proceeding, has been exhausted of the alkali so necessary to those plants.

Now, the plant world has its anomalies like everything else; and it must not be thought that all plants—even of those that live on land—are absolutely dependent upon the soil for their subsistence; neither would it be right to suppose that the nutrient substances usually absorbed by the roots can be taken into the plant in no other way. Nature is inexhaustible in her resources; and the wise old Mother will sometimes infringe her own rules in a surprising manner, as though to teach us, her prying children, that we have not yet fathomed all her wonderful mind, in spite of learned societies, and text-books, and hot-pressed quartos of philosophical transactions, luminous and voluminous, and that she will have her own way, and do singular and unaccountable things, as often as the fancy moves her. Listen to this, by way of illustration: "At New Abbey, in Gallowayshire, in the year 1817, there was growing on the top of a stone wall which measured ten feet in height, a Plane-tree (*Platanus orientalis*) which measured twenty feet in height; and, as it soon exhausted the bare and scanty soil in which the young plant grew, it sent down roots which clung to the side of the wall, and threw out neither bud nor branch until they reached the ground, which was not until several years had elapsed." The narrator adds that "*during all this time the tree must have lived upon the materials supplied by the atmosphere alone*," but clearly this is impossible. The plant must have got its nitrogenous and mineral matter from the wall, in the interstices of which there was also probably an intermittent though sufficient supply of water. Other similar cases are on record.

Marshy places are usually very deficient in certain of the nutrient elements, as nitrogen, potash, and other salts, and plants which grow in such neighbourhoods, being often hard put to to obtain a sufficiency of food, take to crime for a livelihood. Finding, we know not how, that gnats and flies and other species of the great class of *Insecta* contain in their bodies the aliment which is so deficient in the soil, the plants actually prepare traps for the capture of these winged ephemera, which they kill and eat without compunction.

Many have found a difficulty in receiving the statement; nor is a little scepticism surprising. One such plant is the little English Sundew (*Drosera rotundifolia*, fig. 73). The sticky glands at the ends of its red tentacles close round the insect prisoners, and these movements are accompanied by the excretion of a digestive ferment comparable with animal pepsin, which dissolves all the nitrogenous constituents of the victim, just as the gastric juice of our bodies would dissolve an oyster.

There are three British species of Sundew, all of which are insectivorous. The round-leaved (*Drosera rotundifolia*) is perhaps the prettiest, and it is to be met with in several places near London growing amid wet Sphagnum Moss. On the next page is a picture of a colonial species — *Drosera capensis*, the Cape Sundew (fig. 74), which was introduced from the Cape of Good Hope in the year 1875. Its pretty purple flowers are borne on a leafless stem or scape,* which is longer than the leaves but not quite so hairy. In almost every part of the world one or more species of the family may be found. Australia has its twin-leaved Sundew (*D. binata*) and many others; India its *Drosera lunata*, with curious moon-shaped leaves; Africa its few-flowered Sundew (*D. pauciflora*), as well as the Cape species already described; the

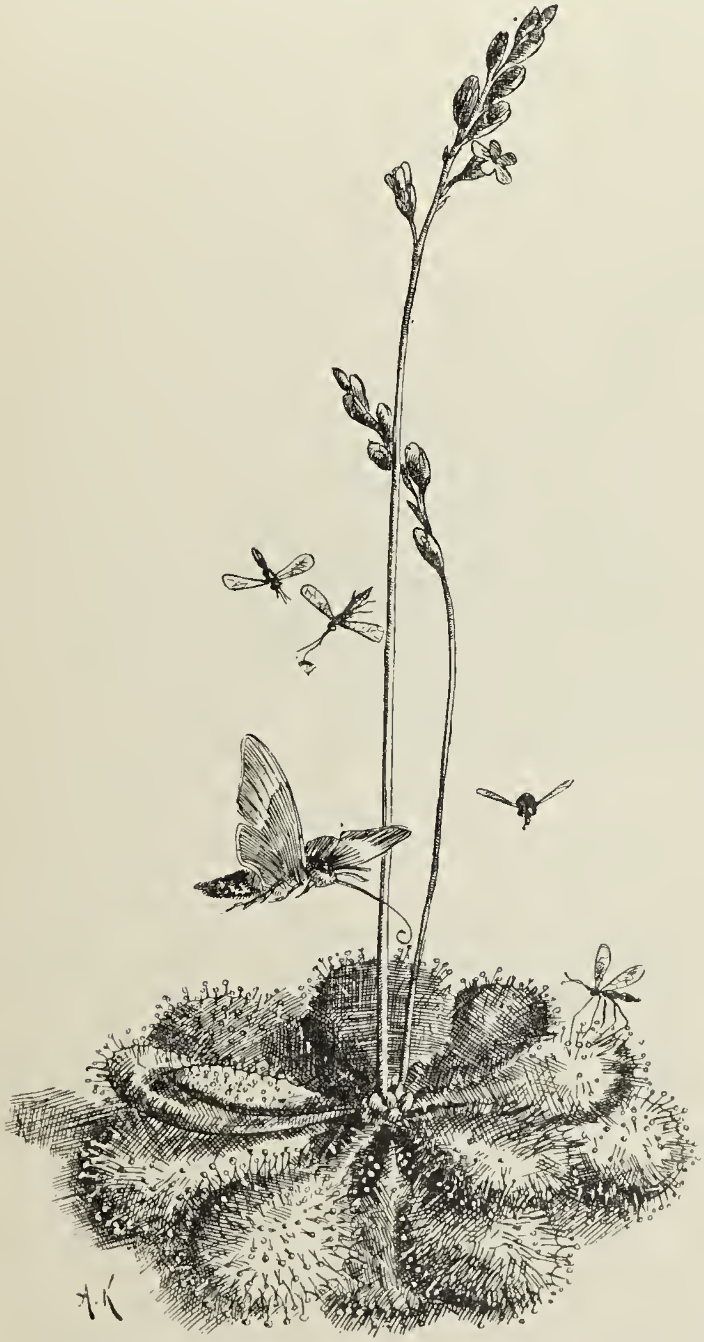

Fig. 73.—Round-leaved Sundew.

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* A leafless stem, springing from the base of a plant and bearing only a flower or flowers, such as is seen in the Primrose, Cowslip, Hyacinth, etc., is a scape.

long-leaved Sundew (*D. longifolia*) is spread over Northern Europe, Canada, and Brazil; while the United States have a pink- and purple-flowered species (*D. filiformis*), which is insectivorous like all the rest.

An American writer, Mrs. Mary Trent, thus speaks of the United States Sundew: "I found it in full bloom, and growing as thick as it could well stand, on either side of an extensive Cranberry plantation. This charming plant, with its pretty pink blossoms, together with the dew-like substance exuding from the glands . . . was one of the most beautiful sights I ever beheld. From former observations I had supposed it caught only small insects, but now found I was mistaken; great Asilus flies were held firm prisoners; innumerable moths and butterflies, many of them two inches across, were alike held captive until they died—the bright flowers and brilliant glistening dew luring them on to sure death. But what is the use of this wholesale destruction of insect life? Can the plants use them? Upon examination I find that after the death of the larger insects they fall around the roots of the plants, and so fertilise them, but the smaller flies remain sticking to the leaves."

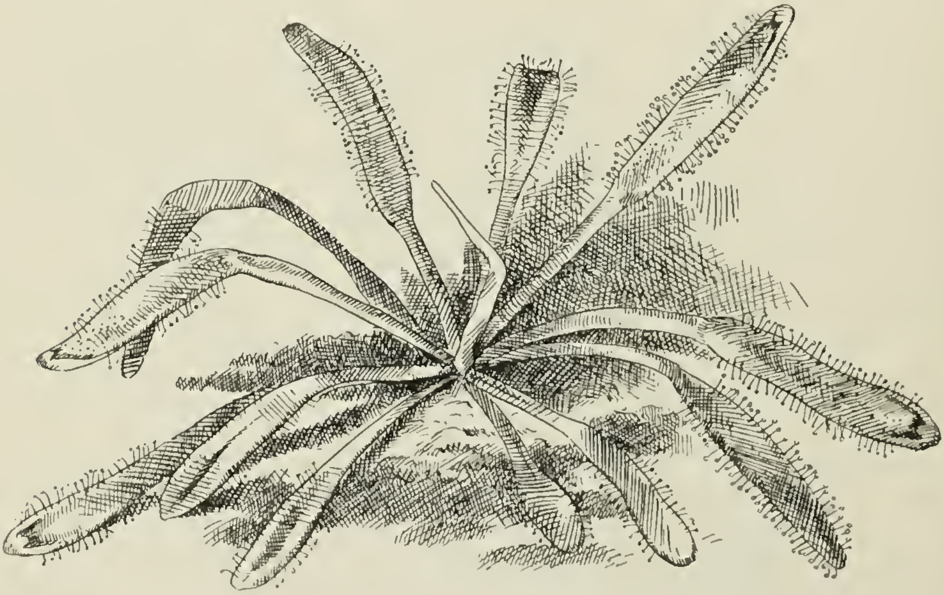

Fig. 74.—Cape Sundew.

Even more remarkable is the discovery made by Mrs. Trent of motile power, not only in the tentacles of this plant, but also in the leaves which bear them. "At ten o'clock," she writes, "I pinned some living flies half an inch from the leaves, near the apex. In forty minutes the leaves had bent perceptibly toward the flies. At twelve o'clock the leaves had reached the flies, and their legs were entangled among the bristles and held fast. I then removed the flies three-quarters of an inch farther from the leaves. The leaves still remained bent away from the direction of the light toward the flies, but did not reach them at this distance."

The Droseras are very partial to rump-steak, and devour it greedily when they get the chance, a fact which Darwin has abundantly demonstrated and which we, in our small way, have also proved; but cinders, and bits of moss and quill, and balls of paper, they will have nothing of. Drops of milk and dissolved isinglass do not appear to come amiss to them, but tea they determinedly eschew, and will not deign to bend their tentacles even a hair's breadth if you sprinkle a little of the refreshing beverage on their leaves. Insects, however, are their special favourites, and the wing of a fly or the leg of an ant will meet with almost instantaneous recognition. Under the circumstances, therefore, it is impossible to credit the Droseras with that virtue of meekness attributed to one at least of the different species by an amiable poetess, who exhorts us "with hearts subdued, like this *meek* flower," to bring our chalices to the "fountain's sacred spring," and so forth. The lady was evidently unacquainted with the habits of the Droseras, and had probably never met with the lines of a fellow poet, who tells us in truer verse:—

And when there's moisture on the Brake,
  The clammy Sundew's glistening glands,
'Mid carmine foliage boldly make
  Slaves of invading insect bands—

though even this is giving the plants a mild character, when we remember that the little slave-makers afterwards devour their captives. The reason why some things are acceptable to insectivorous plants and others not, lies of course in the fact that the former contain a supply of proteid nourishment and the latter have none.

Nearly allied to the Droseras is the dainty little Portuguese Sundew (*Drosophyllum lusitanicum*) (fig. 76), which is also a true insect-eater, though the glandular hairs distributed plentifully over its grass-like leaves are not endowed with the motile power of the true Sundews. This plant is remarkable as having its habitat, not in marshy places, but on sandy shores and dry rocks; in which respect it resembles many of the Australian Sundews, which grow and thrive in the most arid soil. The villagers in the neighbourhood of Oporto hang the plant in their cottages, using it instead of fly-paper.

More wonderful than either *Drosophyllum* and *Drosera*, and belonging to the same order (*Droseraceæ*), is the Venus Fly-trap (*Dionæa muscipula*), a native of North Carolina (fig. 75). Candour compels us to state that it bears no better character than its unnatural cousins, unless, indeed, its very proficiency in crime may be looked upon as a redeeming feature. Its leaves spread in a circle round the crown of the root, and either lie flat upon the ground or gently elevate themselves above the soil. They consist of two very distinct parts—a stalk and a blade. The stalk is a flat, green, leafy expansion, the veins of which are coarsely netted, and it is joined to the blade by a very narrow neck. The blade consists of a roundish, thick, leathery plate, having strong, hidden, parallel veins, which spread nearly at right angles from the central vein or midrib to the margin, and bordered with a row of strong, stiff, tooth-like hairs. When young, the two sides of the blade are placed face to face, and the teeth cross each other; afterwards, when full grown, the sides spread flat, or nearly so, and the teeth then form a firm spreading border. On each half of the blade stand three delicate, almost invisible bristles, uniformly arranged in a triangle; and these are the true sensitive organs of the plant. Let but one of the bristles be touched, and the two sides of the blade spring together with considerable force, the marginal teeth crossing each other so as to enclose securely any small object which may have caused the irritation, be it insect, straw, or seductive morsel of steak. Wonderful to relate, no other part of the leaf is sensible to external impressions. In vain is the back of the leaf disturbed, or the smooth glandular surface pricked and tickled; unless you jar one of the bristles, no irritability is excited, and the blades remain immovably open. The moment the shock is communicated through one of the bristles, the collapse is effected, the leaf assuming altogether the appearance of an iron rabbit-trap when it has closed upon its prey; and if, at this time, an attempt is made to open the leaf, it is violently resisted, in consequence of the rigidity of the parallel veins.

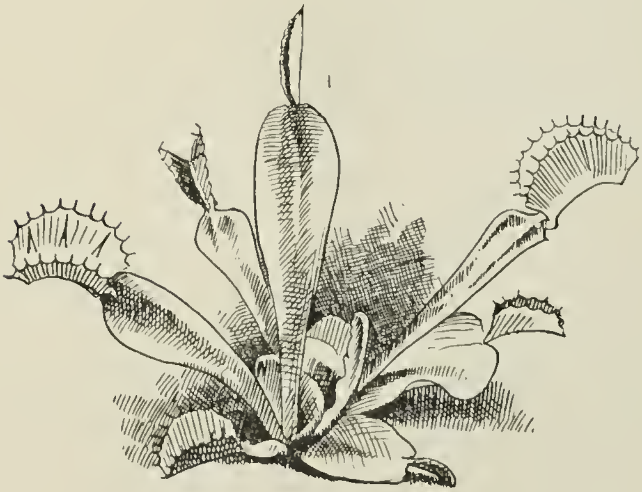
Fig. 75.—Venus Fly-trap.

Like the Sundews, *Dionæa* feeds upon the insects which it catches, for it possesses, like them, the power of digestion. Dr. Burdon Sanderson, in a lecture delivered at the Royal Institution in 1874, thus referred to the digestive power of this plant:—

"When we call this process digestion, we have a definite meaning. We mean that it is of the same nature as that by which we ourselves, and the higher animals in general, convert the food they have swallowed into a form and condition suitable to be absorbed, and thus available for the maintenance of bodily life. We will compare the digestion of *Dionæa* with that which in man and animals we call digestion proper, the process by which the nitrogenous constituents of food are rendered fit for absorption. This takes place in the stomach. It also is a fermentation—that is, a chemical change effected by the agency of a leaven or ferment which is contained in the stomach juice, and can be, like the ferment of saliva, easily separated and prepared. As so separated, it is called pepsin. Consequently, having the ferment, we can easily imitate digestion out of the body. . . . We select for the experiment a substance which, although nutritious and containing nitrogen, is not easily digested—such, for example, as boiled white of egg. In water containing a small percentage of hydrochloric acid, and a trace of pepsin, it is gradually dissolved; but chemical examination of the liquid shows us that it has not been destroyed, but merely transformed into a new substance called peptone, which is afterwards absorbed—that is, taken into the circulating blood.

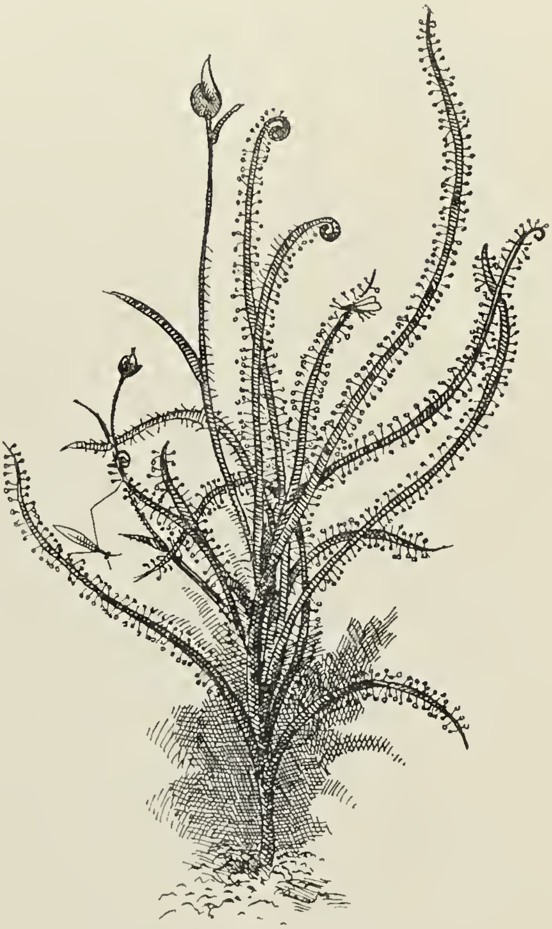
Fig. 76.—Portuguese Sundew.

"Between this process and the digestion of the *Dionæa* leaf the resemblance is complete. It digests exactly the same substances in exactly the same way—*i.e.*, it digests the albuminous constituents of the bodies of animals just as we digest them. In both instances it is essential that the body to be digested should be steeped in a liquid, which in *Dionæa* is secreted by the red glands on the upper surface of the leaf; in the other case by the glands of the mucous membrane. In both, the act of secretion is excited by the presence of the substance to be digested. In the leaf, just as in the stomach, the secretion is not poured out unless there is something nutritious in it for it to act upon; and, finally, in both cases the secretion is acid. As regards the stomach, we know what the acid is—it is hydrochloric acid. As regards the leaf, we do not know precisely as yet, but Mr. Darwin has been able to arrive at very probable conclusions."

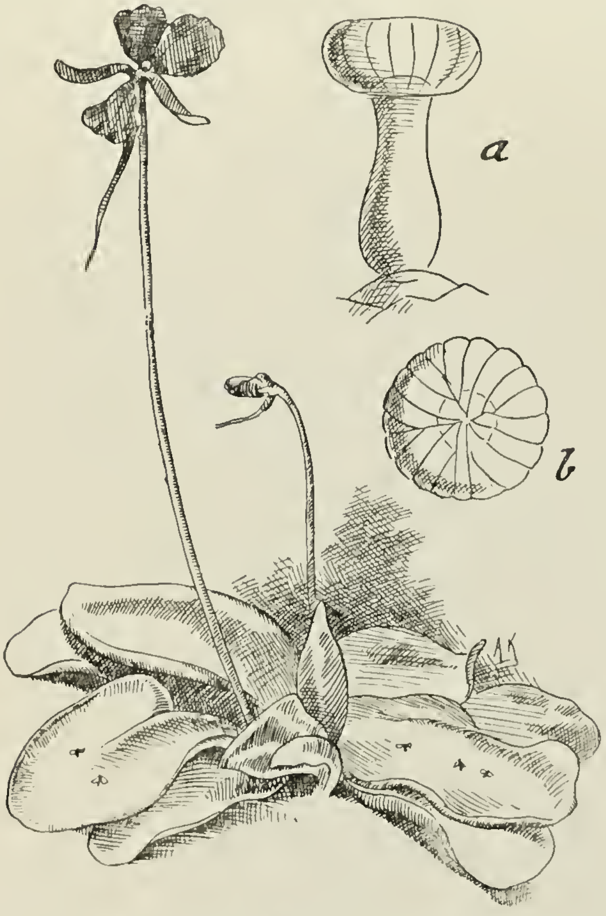

Fig. 77.—Mexican Butterwort. (*a*) One of the glands. (*b*) A gland seen from above.

The Butterworts (*Pinguicula*) constitute another genus of insectivorous plants. One species, *Pinguicula vulgaris*, better known as the Bog-violet or Butter-root, is common in the North of England, while other species are found in different parts of the United Kingdom. We have chosen for representation the Mexican Tailed Butterwort (*Pinguicula caudata*), a lovely greenhouse plant with rich crimson flowers, which was introduced into this country ten or fifteen years ago (fig. 77). *Pinguicula* is a Latin word, a diminutive of *pinguis* (fat); and the name has been given to the genus because its leaves are greasy to the touch. Like the *Droseras*, *Dionæa*, and *Drosophyllum*, all the Butterworts are fly-catchers and fly-digesters; and the large circular glands, supported upon footstalks of varying lengths, which thickly cover the upper surface of the leaves, are the fatal traps (*a* and *b*). The incurved leaf edges are devoid of glands, and appear to serve the double purpose of preventing insects from being washed away by the rain and of retaining the secretion, which might otherwise flow off the leaf and get wasted. When an insect alights or is blown on to the leaf, "it gets entangled in the sticky secretion, and it is killed, and speedily killed, by the secretion adhering to and closing up the spiracles by which the insect breathes" (Sanderson).

Perhaps it is hardly to be wondered at that the *Pinguiculas*, like the *Droseras*, have connections outside their own immediate family. The Butterworts and the Bladderworts are, in fact, first-cousins; and who has not heard of the carnivorous doings of the latter? Our illustration shows the Common or Greater Bladderwort (*Utricularia vulgaris*), an inhabitant of ditches and deep pools (fig. 78). The plant is common enough in this country. Notice carefully the many little bladders attached to the leaves, a characteristic of all the *Utricularias*. These bladders, which are of a green, purple, or pink colour, "are," according to Miss Pratt, "at first filled with water; but during the time of flowering the water escapes, and they become filled with air, so as to buoy up the plant above the surface, that it may have the light and air necessary for its development. When the flowering is over, however, and these little buoyant air-vessels are no longer needed, the bladders become filled with water, and bear the plant down again, that it may ripen its seeds and sow them in the mud at the bottom." The bladders are of curious structure. Each has an aperture closing with an elastic valve, which is of much thinner texture than the vesicle to which it is attached. It opens inwards, and aquatic insects, incautiously entering the little door, like the fly in the nursery poem, "ne'er come out again."

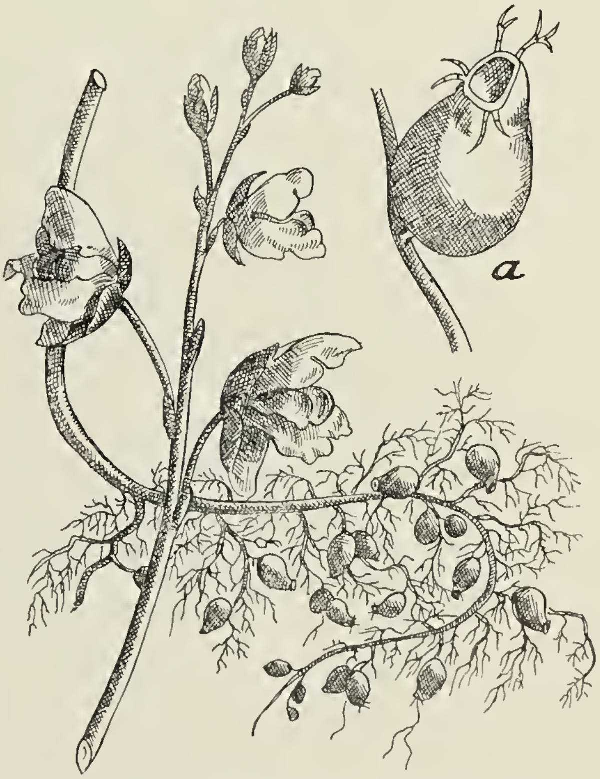

Fig. 78.—Common Bladderwort. (*a*) One of the bladders greatly magnified.

The New Jersey lady whose interesting account of *Drosera filiformis* has been quoted has also studied to some purpose the carnivorous habits of an American species of Bladderwort (*U. clandestina*). She says: "The entrance into the bladder has the appearance of a tunnel net, always open at the large end but closed at the other extremity. The little animals seemed to be attracted into this inviting retreat. They would sometimes dally about the open entrance for a short time, but would sooner or later venture in, and easily open or push apart the closed entrance at the other extremity. As soon as the animal was fairly in, the forced entrance closed, making it a secure prisoner. I was very much amused in watching a Water-bear (*Tardigrada*) entrapped. It went slowly walking round the bladder, as if reconnoitring, very much like its larger namesake; finally it ventured in at the entrance, and easily opened the inner door and walked in. The bladder was transparent and quite empty, so that I could see the movements of the little animal very distinctly, and it seemed to look around as if surprised to find itself in so elegant a chamber; but it was soon quiet, and on the morning following it was entirely motionless, with its little feet and claws standing out as if stiff and rigid. The wicked plant had killed it very much quicker than it kills the snake-like larva. *Entomostraca*, too, were often captured—*Daphnia*, *Cyclops*, and *Cypris*. These little animals are just visible to the naked eye, but under the microscope are beautiful and interesting objects. The lively little *Cypris* is encased in a bivalve shell, which it opens at pleasure, and thrusts out its feet and two pairs of antennæ, with tufts of feather-like filaments. This little animal was quite wary, but nevertheless was often caught. Coming to the entrance of a bladder, it would sometimes pause a moment and then dash away; at other times it would come close up, and even venture part of the way into the entrance, and back out as if afraid. Another, more heedless, would open the door and walk in, but it was no sooner in than it manifested alarm, drew in its feet and antennæ, and closed its shell. But after its death the shell unclosed again, displaying its feet and antennæ. I never saw even the smallest animalcule escape after it was once fairly inside the bladder."

Mrs. Trent had now settled to her satisfaction that the animals were entrapped, killed, and slowly macerated by the plant; but she had still to ascertain whether the plant really digested them. A critical and microscopic examination of the contents of several of the bladders was forthwith instituted, and as a result of this examination Mrs. Trent was forced to the conclusion, not only that the habits of the *Utricularis* come nearer to the animal than that of any other of the carnivorous plants, but that the bladders with which they are furnished are, in truth, so many little stomachs, digesting and assimilating animal food.

Besides containing Bladderworts of the British type, like *U. clandestina*, the West Indies possess some of a type not found in this country. During his stay in those islands, Kingsley came upon certain specimens, growing out of the damp clay, which "were more like in habit to a delicate stalk of flax, or even a bent of grass, upright, leafless or all but leafless, with heads of small blue or yellow flowers, and carrying, in one species, a few very minute bladders about the roots, in another none at all. A strange variation from the normal type of the family," continues the eloquent canon, "yet not so strange, after all, as that of another variety in the high mountain woods, which, finding neither ponds to float in nor swamp to rot in, has taken to lodging as a parasite among the wet moss on tree-trunks; not so strange, either, as that of yet another, which floats, but in the most unexpected spots—namely, in the water which lodges between the leaf-sheaths of the wild Pines, perched on the tree-boughs, a parasite on parasites*; and sends out long runners, as it grows, along the boughs, in search of the next wild Pine and its tiny reservoirs" (*At Last*, p. 314).

We must not quit this subject without offering a few remarks on the Pitcher-plants. If the little bladders of *Utricularia*, which measure scarcely an eighth of an inch in length, are so many stomachs, digesting and assimilating animal food, what shall we say of the pitchers of *Nepenthes* and *Sarracenia*, which fulfil a similar purpose, and occasionally measure, in the case of *Nepenthes Edwardsiana* twenty inches from lid to leaf attachment, and in that of *Sarracenia flava* upwards of three feet in height? The pitchers really form part of the leaf structure, those in *Nepenthes* being simply abnormal expansions of the *lamina*, or blade of the leaf, while those in *Sarracenia* are peculiar developments of the petiole, or leaf-stalk, their lids (where lids are formed) probably constituting the blade.

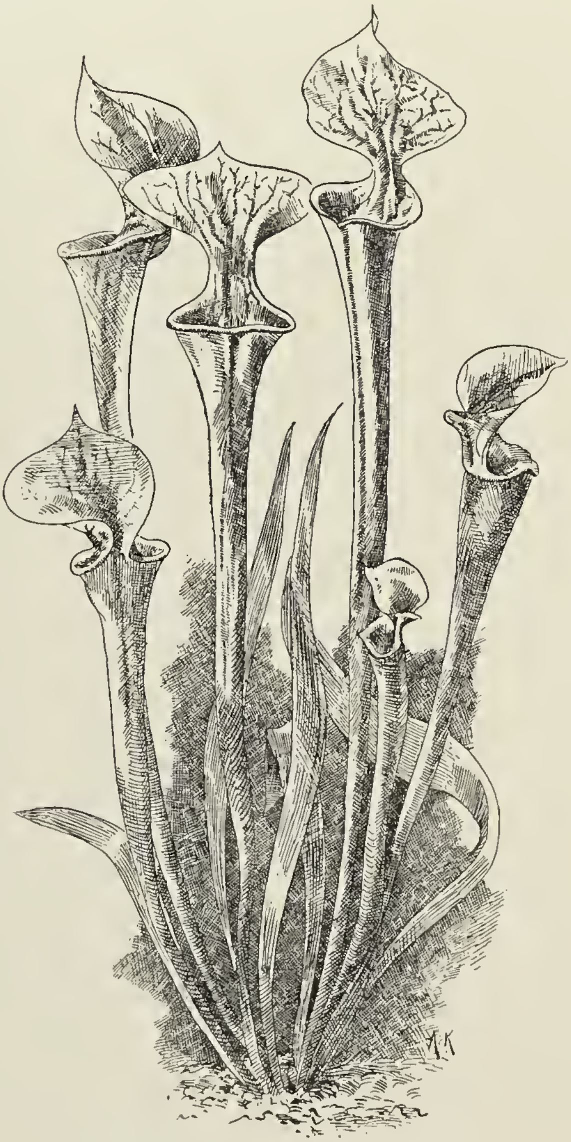

Fig. 79.—*Sarracenia flava* or *ornata.*

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* None of these is parasitic in the botanical use of the term.

We may begin with the *Sarracenias*, popularly known as Indian Cups, Side-saddle-flowers, and Trumpet-leaves. In fig. 79 we have the beautiful but treacherous *Sarracenia flava* or *ornata*, which bears a magnificent flower of a rich canary-yellow, sometimes measuring as much as eight inches in diameter. The long trumpet-shaped erections are the leaves, which have been united at their margins to form pitchers (though some regard these pitchers as hollow leaf-stalks), and which usually contain a fluid—not rain-water—of a bland and somewhat mucilaginous taste. Were the living specimens from which this drawing was made at hand, we might show, by slitting one of the tubular leaves, a black mass of organic matter at the base of the tube, consisting of clotted flies in all stages of digestion and decay. Not long since the attendant in charge of the Victoria Regina House at Kew kindly opened one of the leaves in our presence; and there, lying thickly together like the crushed currants in a Garibaldi biscuit, were the victims of Sarracenian greed. It was not an appetising sight.

Professor Asa Gray, the distinguished American botanist, studied these plants closely, and has given an amusing account of what takes place inside the long pitchers when once they have been entered by insect visitors. "After turning back the lids of most of the leaves," he writes, "the flies would enter, a few alighting on the honeyed border of the wing, and walking upward, sipping as they went to the mouth, and entering at the cleft of the lower lips; others would alight on the top of the lid, and then walk under the roof, feeding there; but most, it seemed to me, preferred to alight just at the commissure of the lips, and either enter the tube immediately there, feeding downward upon the honey pastures, or would linger at the trunk, sipping along the whole edge of the lower lip, and eventually near the cleft. After eating (which they generally do with great caution and circumspection), they begin again to feed, but their foothold, for some reason or other, seems insecure, and they occasionally slip, as it appears to me, upon this exquisitely soft and velvety declining substance. The nectar is not exuded or smeared over the whole of this surface, but seems disposed in separate little drops. I have seen them regain their foothold after slipping, and continue to sip, but always slowly and with apparent caution, as if aware that they were treading on dangerous ground. After sipping their fill they frequently remain motionless, as if satiated with delight, and, in the usual self-congratulatory manner of flies, proceed to rub their legs together, but in reality, I suppose, to clean them. It is then they betake themselves to flight, striking themselves against the opposite sides of the prison-house, either upwards or downwards, generally the former. Obtaining no perch or foothold, they rebound off from this velvety microscopic *chevaux de frise*, which lines the inner surface, still lower, until by a series of zigzag but generally downward falling flights, they finally reach the coarser and more bristly pubescence of the lower chamber, where, entangled somewhat, they struggle frantically (but by no means drunk or stupefied), and eventually slide into the pool of death, where, once becoming slimed and saturated with these Lethean waters, they cease from their labours. After continued asphyxia they die, and after maceration they add to the vigour and sustenance of the plant. This seems to be the true use of the limpid fluid, for it does not seem to be at all necessary to the killing of the insects (although it does possess that power); the conformation of the funnel of the fly-trap is sufficient to destroy them. They only die the sooner, and the sooner become liquid manure."

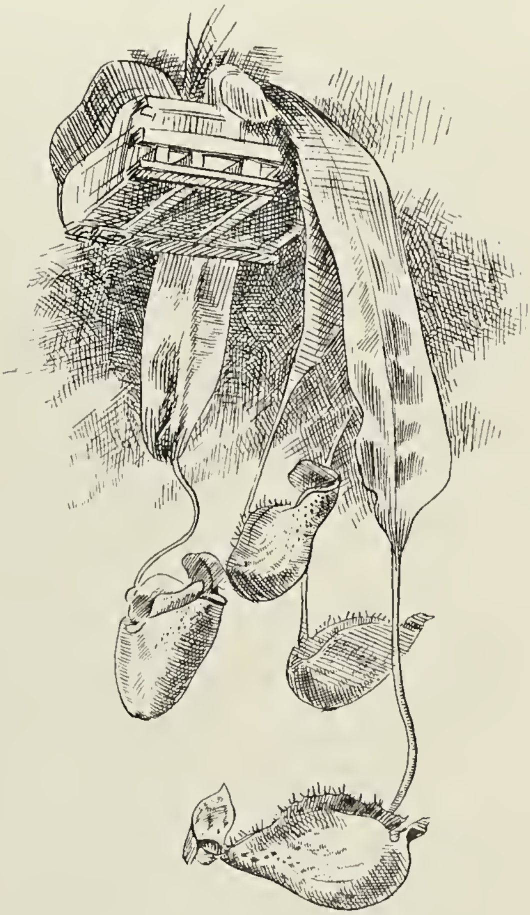

Fig. 80.—*Nepenthes edinensis.*

In the *Nepenthes* we have another family of irreclaimable insect feeders. Each of the pouch-like prolongations of their leaves is—like the tall cups of the *Sarracenias*—a kind of external stomach which digests solid food. Here is a beautiful hybrid, *Nepenthes edinensis*, which is to be found luxuriating at Kew (fig. 80). Its pitchers measure three or four inches in length, but in most of the *Nepenthes* they are larger. A Bornean species, probably *Nepenthes villosa*, noticed by Dr. Hooker, "has pitchers which, including the lid, measure a foot and a half, and the capacious bowl is large enough to drown a small animal or bird." These Nature-made water-vessels (or their contents) have proved, indeed, in more instances than one, the salvation of travellers, in places where streams are few and droughts a common occurrence. On one occasion two Englishmen were proceeding from Dondera Head, the southern extremity of the island of Ceylon, towards Candy in the interior, when their water gave out. Overcome by thirst, they sank down, weak and despairing, at the foot of a palm-tree, and waited for death. At that moment a tame monkey, which most providentially they had brought with them, ran eagerly forward, as if searching for something. On witnessing the action, the travellers were inspired with new hope, and one of them got up and followed the animal. The little fellow led him to a spot at no great distance, where a number of *Nepenthes*, probably of the species *distillatoria*, were growing (fig. 81), and, to his unspeakable joy, the pitchers contained an abundant supply of water. Thus their lives were preserved.

Though the pouches of *Nepenthes distillatoria* are comparatively plain, in many species these singular structures are richly marked and show both beauty and variety of form. Observe, for example, the exquisite Nature-painting on the bowl and lid of *Nepenthes mixta*, and the curious corrugated rim with which it is provided (fig. 82). This rim is not merely ornamental. It strengthens the mouth of the pouch and keeps it distended; and moreover, it secretes the honey by means of which insects are attracted to the plant and eventually into the death-pool below.

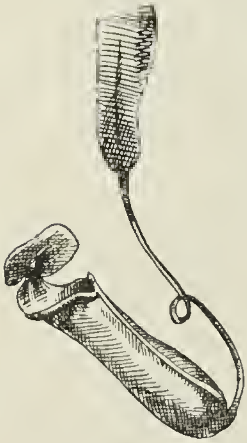
Fig. 81.—*Nepenthes distillatoria.*

Another interesting species of pouch-like fly-catcher, though not belonging to the *Nepenthes*, is the diminutive and almost stemless New Holland Pitcher-plant (*Cephalotus follicularis*), a native of Western Australia, where it was discovered by the French naturalist, Labillardière, more than seventy years ago (fig. 83). Dr. Tait has found that the acid secretion of certain glands on the inner surface of the pouches of this plant will digest shreds of albumen and insects, and therefore that the plant is truly carnivorous; and certainly the pitchers are wonderfully adapted for the capture and retention of their living prey. The corrugated rim "ends abruptly on the inner margin in a row of inflexed teeth," and "below the rim is a ledge extending round the inside of the pitcher, with its acute edge projecting downwards into the cavity, forming a kind of contracted neck. This is called the conducting shelf. Below this, again, the upper two-thirds of the walls are smooth and glandular. At the lower margin of this smooth surface an oblique curved elevation extends on each side, and below all is the bottom of the pitcher, which is smooth and without glands. The surface of the conducting shelf is furnished with hairs projecting downwards."

A reflective person is apt to inquire, Why were insectivorous plants ever given a place in Creation? and it certainly does seem strange that objects in the Vegetable World should be made the instruments of destruction to objects in the sister kingdom; though we have long been reconciled to the existence and necessity of an opposite condition of

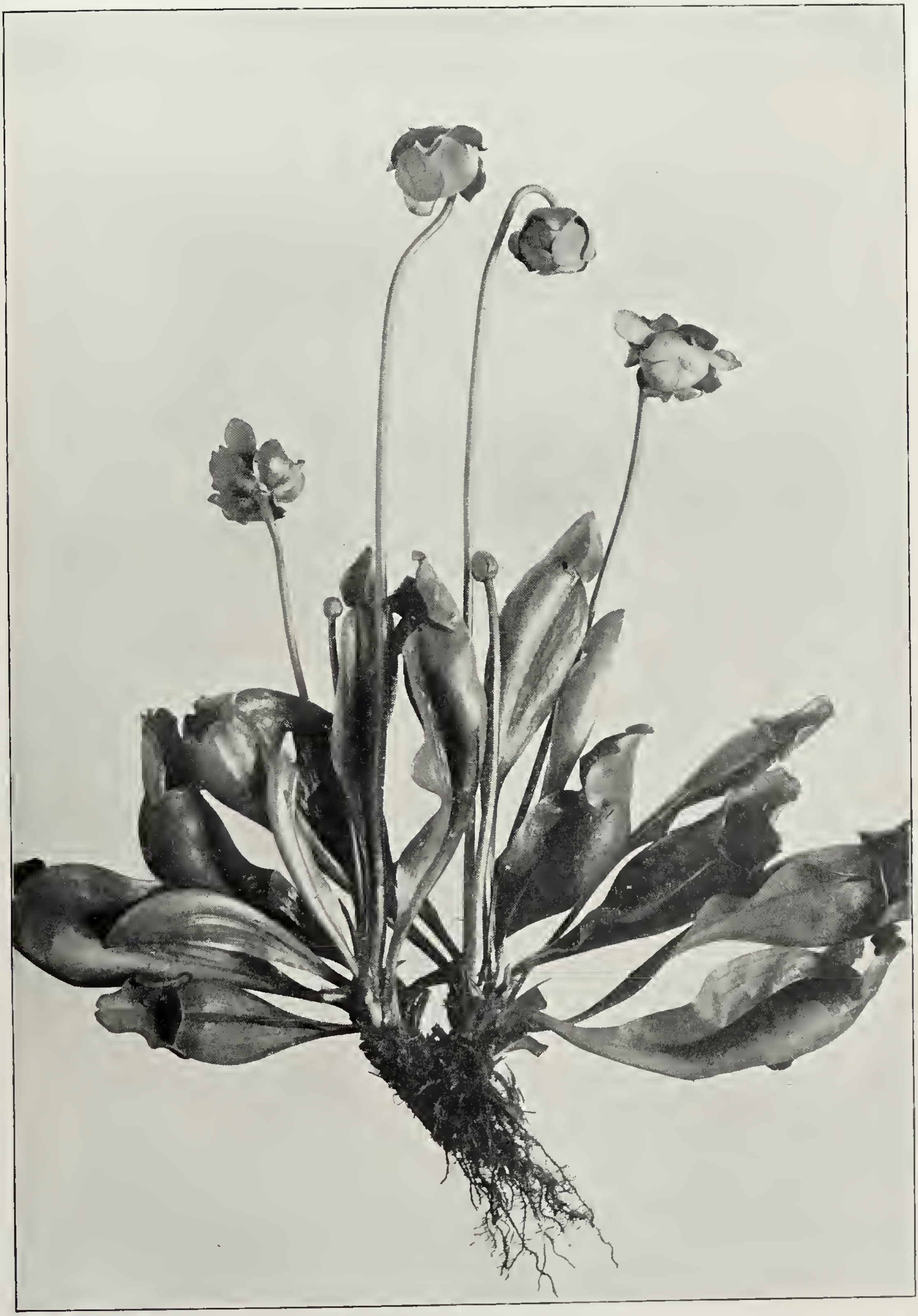

Photo by Henry Troth.

A PITCHER-PLANT.

A species of Cephalotus. Partly lives on insects, which it traps and kills, and from whose bodies it extracts the juices that are necessary to its own life.

PLATE V.

things. That ants and aphides should thrive and grow fat by feeding on the sappy tissues of plants appears to us a natural and even justifiable provision, but that the plants should retaliate by setting traps for their tormentors is not so easily accounted for; and we are immensely shocked when we find that not a few of them actually feed upon their captive enemies. Is not this, we cry—

A sort of retrograding?
  Surely the fare
  Of flowers is air,
  Or sunshine sweet.
  They shouldn't eat
Or do aught so degrading.

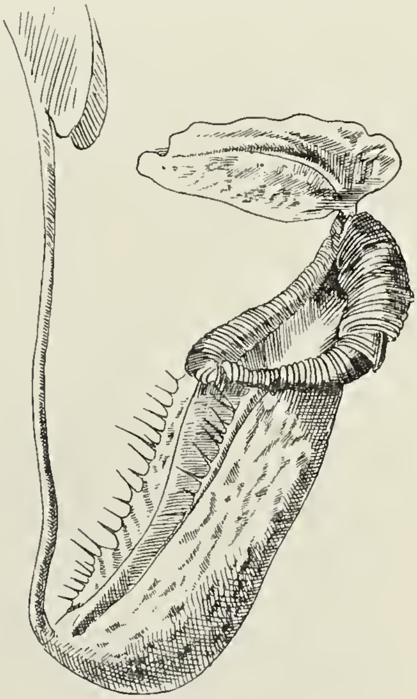

Fig. 82.—*Nepenthes mixta.*

But what these wilful children of Flora *should* do, and what they actually do, are of course two very different things; and when all is told, and poets and moralists have had their say, the stubborn fact remains that certain plants *do* feed on insects; and that nitrogen, potash, etc., may be obtained from other sources than the soil, and be absorbed into the plant by other organs than the root. At the same time it should never be forgotten that the root is the *chief* organ of absorption—that is, of all the nutrient elements save carbon—and, moreover, that insectivorous plants occupy but a small corner of the Vegetable Kingdom. As already remarked, they have apparently taken to this method of obtaining nitrogenous food because there is so little of it in the soil where they grow.

It may be asked, How is it that the fluid from the soil is able to force its way through the membranous cell-walls of the root-hairs and to pass upwards into the plant? The question suggests another, namely, How is it that water is drawn up into a piece of loaf-sugar or a sponge? though by fencing the first question in this manner one is only suggesting a solution to the tail-end of the difficulty, nor this, unless something is known of capillary attraction.

But how is it that the fluid of the soil gains entrance into the closed cells? A merely verbal explanation, however clear, would be dry and unenlightening. We might talk about endosmose and exosmose and the power of passing through porous diaphragms for hours, and still fail to convey a definite impression on the subject. An experiment in this case will save a world of laborious explanation. For this experiment nothing more is required than a bowl of distilled water, some sugar in solution, a small length of glass tubing, and a couple of pieces of bladder to close up the ends.

The experiment is performed in the following manner: Close up one end of the tube with a piece of bladder and pour in the solution of sugar; then close up the other end, and immerse the whole in the bowl of water. It will presently be found that the bladder at both ends has become distended, in consequence of an increase of volume of the fluid in the tube, the increase being due to an inflow of the distilled water in which the tube is immersed. This transmission of a fluid through a porous partition from the exterior to the interior is called *endosmose* (Greek *endon*, within; *ōsmos*, impulsion). On applying a little of the distilled water to the lips, it will be found to have acquired a slightly sweet taste, a small portion of the sugary solution having passed out through the bladder. Here, then, is evidence that two currents, of which the inward flow of water is the chief, have been set up. With these results in view, substitute in imagination a root-hair for your glass tube, and for your bladder the exterior cell-walls of the hair, and the experiment will have been made to some purpose.

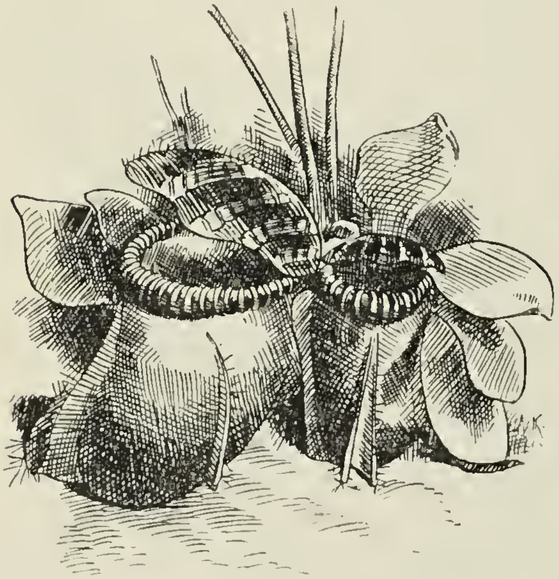

Fig. 83.—New Holland Pitcher-plant.

That there is a slight *outward* flow of sap from the plant, in addition to the more important *inward* passage of water and its concomitants, may be shown in another way. If a plant be grown with its roots in water, the surrounding fluid is soon found to contain some of the peculiar substances contained in the descending sap. Thus a Pea or Bean will disengage a gummy matter, a Poppy will communicate to the water an opiate impregnation, and a Spurge will give it an acrid taste. This passage of the sap through the cell membranes, from within outwards, is called *exosmose* (Greek *exo*, outside; *ōsmos*, impulsion).

Once the fluid from without has entered the root-hairs, it diffuses from cell to cell till it reaches the fibro-vascular system—that wonderful arrangement of vessels and woody cells which forms the framework or skeleton of the plant; and so it mounts and mounts, chiefly by way of the wood elements, from root to stem, from stem to branch, from branch to slender twig, till it reaches the leaves—as little changed during its whole passage as the water which passes through a pump. The wind which rocks the trees and plants to and fro assists in this process, and the leaves also assist, though in quite a different manner. The latter, indeed, are the busiest organs of the plant, as we shall see in the next chapter, when we shall consider their wonderful structure and functions.

The rate at which the watery sap courses up the stem may be gathered from Kingsley's vivid description of the Liantesse (*Schnella excisa*), a West Indian Water-vine, whose singular stem, hanging in loops twenty feet high, he likens to a chain-cable between two flexible iron bars. At one of these loops, "about as thick as your arm," writes the canon, "your companion, if you have a forester with you, will spring joyfully. With a few blows of his cutlass he will sever it as high up as he can reach, and again below, some three feet down; and while you are wondering at this seemingly wanton destruction, he lifts the bar on high, throws his head back, and pours down his thirsty throat a pint or more of pure cold water. This hidden treasure is, strange as it may seem, the ascending sap, or rather the ascending pure rain-water which has been taken up by the roots, and is hurrying aloft to be elaborated into sap, and leaf, and flower, and fruit, and fresh tissue for the very stem up which it originally climbed; and therefore it is that the woodman cuts the Water-vine through first at the top of the piece which he wants, and not at the bottom; for so rapid is the ascent of the sap that if he cut the stem below, the water would have all fled upwards before he could have cut it off above" (*At Last*, p. 159).

So much for the ascending sap. Our next subject will be one of more interest and importance—the *de*scending or elaborated sap.

CHAPTER V

THE DESCENDING SAP

And now returning through the knotty stem
By broader routes, a copious, nutrient stream.

WE saw in Chapter III. that an ordinary foliage leaf consists of three distinct kinds of tissue, which may be popularly described as the veins, the fleshy substance between the veins, and the thin enveloping skin. Here is a microscopic view of the transverse section of part of a Rhododendron leaf (fig. 84). Upwards of twenty layers of cells are packed in the thickness of this single leaf—a fact to arrest attention. The double line of cells lettered *a* belongs to the epidermis of the upper side of the leaf; *b* shows the fibro-vascular bundle of a vein in cross-section; *c* the parenchyma of the ground tissue, easily to be recognised in the actual leaf by the chlorophyll corpuscles contained in the cells; *d* are air cavities between the cells, botanically known as *intercellular spaces*; and the single row of cells at the bottom of the section belongs to the epidermis of the under side of the leaf.

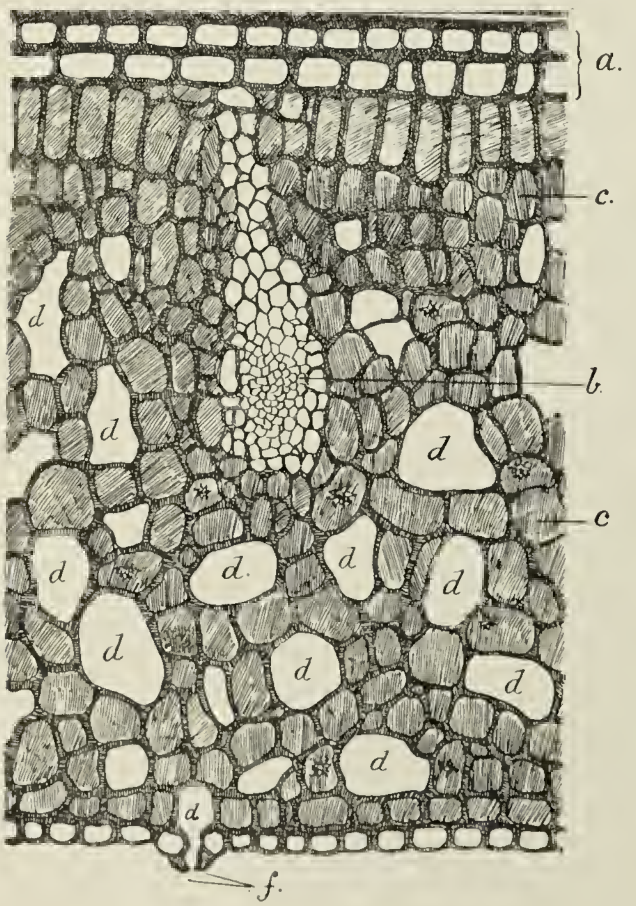

Fig. 84.—Transverse section of a part of a Rhododendron leaf.

But some cells have yet to be spoken of which play a most important part in the life of the plant, and to which particular attention should be given. A pair of these cells are lettered *f* in the drawing. They project from the lower line of epidermal cells, and form the two lips of a little mouth, which communicates with one of the intercellular spaces (*d*); moreover, they contain chlorophyll, which the epidermal cells do not. To speak of these projecting cells as "lips" is not fanciful, for the orifice between them is a veritable mouth, and the name which physiologists apply to such openings is *stomata*, which is simply the Greek word for "mouths" (figs. 85–87).

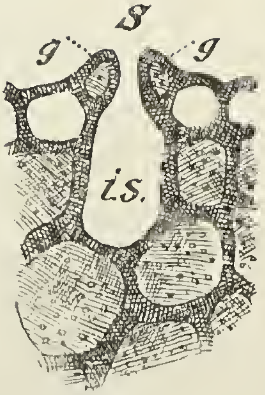

Fig. 85.—Form of stomata seen in transverse section from leaf of a Rhododendron.

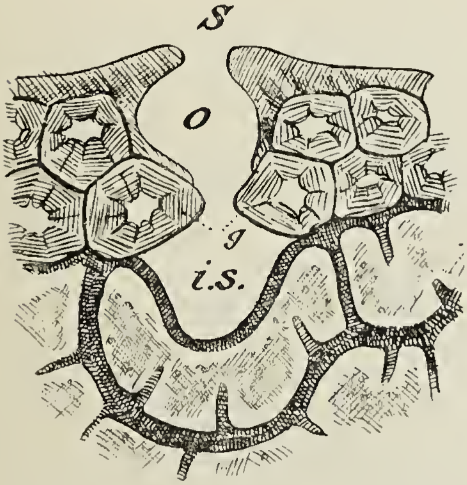

Fig. 86.—Form of stomata seen in transverse section from leaf of a Scotch Fir (*Pinus sylvestris*).

The stomata, indeed, are little mouths or crevices in the epidermis, caused by the separation of certain cells in the course of growth; and these cells form the "lips" of the mouth, and are known as *guard-cells*. Each is shaped like a crescent, their points or horns meeting to form the *stôma* or mouth; and it is by means of these peculiar structures that the plant transpires. The tiny openings establish a communication between the atmosphere and the air chambers or intercellular spaces in the interior of the plant, the passing in and out of gases being regulated in a beautiful manner by the guard-cells.

Fig. 88 represents a minute piece of the epidermis of the Madder-plant (*Rubia tinctoria*), in which three of the stomata are plainly shown; but far better for examination is a beautiful plant of the Daffodil order—Amaryllidaceæ—known by the very ugly name *Hippeastrum*. It is a variety of *H. Ackermanni*, one of the largest flowering species of the genus. As a rule the clefts vary in length from $\frac{1}{30000}$th to $\frac{1}{125000}$th of an inch, and so abundant are they on some leaves that a square inch of tissue may contain as many as 250,000 of them. They are met with only in those parts of the plant

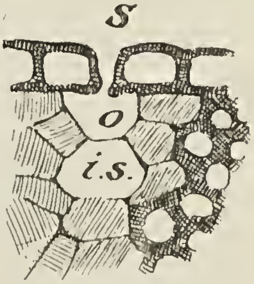

Fig. 87.—Form of stomata seen in transverse section from stem of a Field Horse-tail (*Equisetum arvense*).

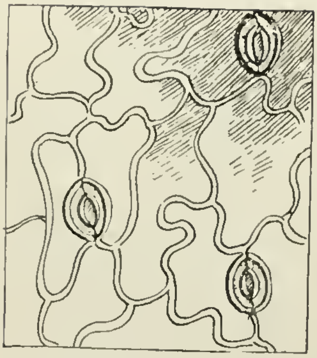

Fig. 88.—Cells in the epidermis of leaf of the Madder-plant, with stomata.

where they are actually needed, for our protoplasts work on economic principles, never wasting their forces. Hence you will look in vain for the stomata on leaves which grow under water,* or on the under surface of floating leaves—the very place where they are most plentiful in land plants. Plants of the Cactus tribe (*Cacteæ*) and some tropical Euphorbias—whose leaves, like those of the Cacti, hereafter to be spoken of, have been metamorphosed into spines and thorns for protective reasons—develop their stomata on the fleshy succulent stems. From roots—if we except the green-celled aerial roots of a few epiphytes, such as the Tree-orchids of the tropics—they are entirely absent. In the interesting Polar-plant (*Silphium laciniatum*) the stomata are about equally distributed on both sides of the broad flat leaves—a very necessary provision, because of the peculiar position of the leaves, both faces of which are in every case equally illuminated by the sun. This is the case with most, if not all, plants with vertical leaves.

A curious fact, not unconnected with our present subject, has been brought to light by Dr. M. C. Cooke, in relation to *Bomarea Carderi*, a handsome climbing plant of Colombia. The plant has long lance-shaped leaves, and Dr. Cooke has pointed out that the *under* surfaces of the blades of these leaves are exposed to the light, owing to a twist in the leaf-stalk (fig. 90). To give additional interest to the discovery, a competent physiologist, Mr. W. S. Gilburt, to whom specimens were submitted, ascertained that the entire structure of the leaves is reversed, in order to fulfil the conditions of their reversed position; the under surface being smooth, and presenting the usual characteristic epidermal cells of an *upper* surface; while the true upper surface is fitted to do duty for the former. No satisfactory reason has yet been assigned for the twisting of the leaf-stalk, and if ever the phenomenon is accounted for it will probably be by one who has studied the plant closely in its native habitat.†

It has been shown that the presence of light is most essential to the development of perfect and vigorously acting stomata. This fact—with other related facts—has been well illustrated in the case of one of the commonest of the Liverworts, *Marchantia polymorpha* (fig. 91). The young plant, when first separated as a kind of bud from its parent, exhibits no stomata or roots.* "It has been ascertained by repeated experiments," says Dr. Carpenter, "that stomata and roots [really 'rhizoids'] may be caused to develop themselves in either of the two sides; the stomata † (fig. 92) being always formed on the upper surface, under the influence of light, and the . . . [rhizoids] proceeding from the lower towards darkness. But if the surfaces be reversed *after* the reproductive organs have been developed to a certain point, so that the stomata be directed towards the ground, and the . . . [rhizoids] be made to rise into the air, the little plant will right itself, by twisting itself round, so as to bring its surfaces to their former position. Further, when plants of a higher description are grown in darkness, the stomata are developed very imperfectly, or not at all. Thus we have an example of the very important effects of the stimulus of light upon the vegetable structure, not only in covering its actions, but in influencing its development" (*Vegetable Physiology and Botany*).

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* *Water stomata*, however, are found in some plants. "These are situated over the ends of small masses of specially modified parenchymatous cells (glandular cells), in which vascular bundles terminate, and which are known as *water glands.*" Water stomata give off water and various substances in solution.—*Text-book of Biology*, p. 92.

† *Freaks and Marvels of Plant Life*, pp. 196, 197.

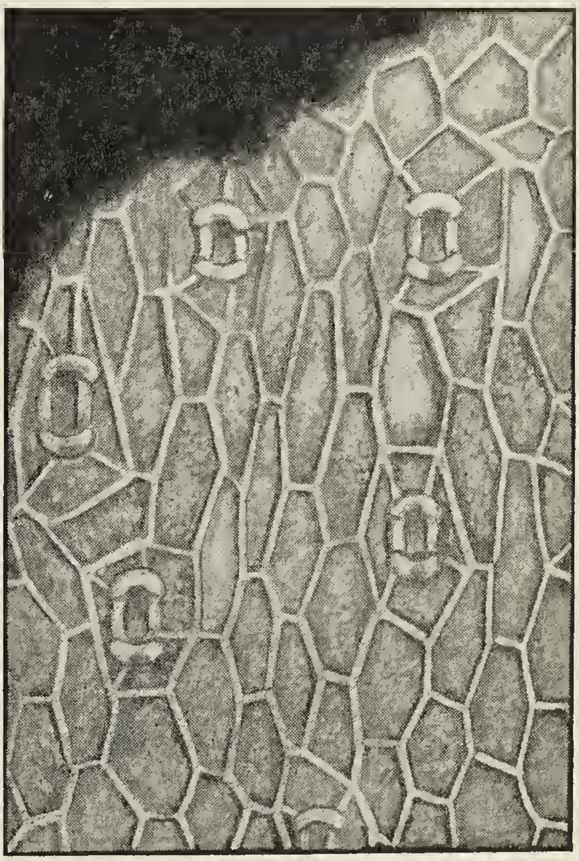

Fig. 89.—Horizontal section through the epidermis of a Yucca leaf, showing stomata.

We have said that the stomata are the organs through which the plant transpires. The condensation of water on the glass surface of an ordinary fern-case is a familiar instance of *transpiration*; though doubtless some of the vapour is due to evaporation from the soil. By placing a piece of cardboard, through which a small hole has been made for the insertion of a well-developed leaf-shoot, over the mouth of a tumbler of water, and covering the whole (leaf-shoot and tumbler) with a bell-glass, evaporation will be prevented, and the watery deposit forming on the inside of the glass will soon furnish proof that water is transpired from the leaves. Hence the necessity for keeping the roots of plants well supplied with water; for if the loss by transpiration be greater than the quantity supplied by the roots, the conducting parts (as the stem and branches) quickly suffer; and when at length the evaporation from the more delicate organs can no longer be compensated, they lose their stiffness or turgidity, hang down from their own weight, and wither.* The flagging of leaves, so often noticed in the potting and bedding-out of plants, is due to the same cause. The delicate root-hairs, by which alone absorption from the soil is effected, get destroyed in the process of transplanting, and thus the upward flow of crude sap to the leaves is temporarily arrested. In cases of this kind, transpiration should be artificially checked by shading the plants from the light till such time as new root-hairs have been found, when absorption will again take place.

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* More correctly *rhizoids*. *Rhizoids* correspond to the root-*hairs* of Flowering Plants.

† Or, rather, *stomata-pores*. They are really pores in the outermost layer of tissues (for the thallus has no true epidermis), and each pore leads into an air chamber much larger than itself, in which is contained the assimilating tissue of the thallus.

Thus we see how important a part the leaves play in connection with the upward flow of sap. Transpiration, which is carried on chiefly through the stomata, not only gets rid of the superfluous water, but sets up a rapid movement of the crude sap from the root to the leaves, drawing it upwards, somewhat as the oil is drawn upwards in the wick of a burning lamp. This giving-off of water by plants is often of considerable benefit to the regions in which the plants are found. "It is a well-known fact," says Dr. Nathaniel Ward, the inventor of the Wardian case, "that many hilly countries have been rendered quite sterile, in consequence of the indiscriminate destruction of their trees, the roots of which, taking up more water from the deep-seated springs than the plants require for their own use, distil the surplus through the leaves upon the ground, forming so many centres of fertility. 'Spare the forests, especially those which

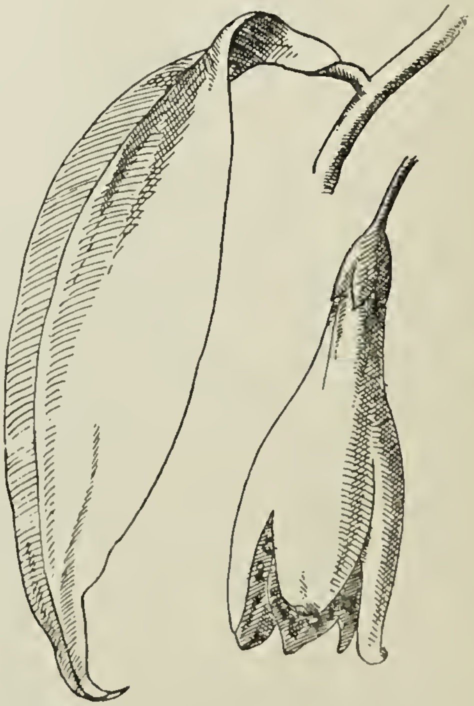

Fig. 90.—Leaf and flower of *Bomarea Carderi.*

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* Thomé's *Lehrbuch der Botanik*, p. 103.

contain the sources of your streams, for your own sakes, but more especially for that of your children and grand-children.' "* Needless to add, the quantity of water given off in the manner described renders the solutions denser in the leaves than in the stems—a point that will come before us again presently.

Much more devolves upon the leaves, however, than the giving off of superfluous moisture. We have seen that the crude sap, which contains in solution the nutritious principles, undergoes but little change during its passage from the root to the leaves; and also that the substances thus introduced into the plant are, without exception, *inorganic compounds*. Yet these compounds, if they are to be of any service to the plant, must be converted into organic matter, in order that this, in turn, may form the plastic material or protoplasm out of which new vegetable structures, such as cells, vessels, etc., may be built up. In other words, the food must be *assimilated* by the plant; and this necessity pertains not merely to the nutrient substances absorbed from the soil, but also to the carbon dioxide derived from the atmosphere.

Assimilation, indeed, is found to consist essentially in the decomposition of carbon dioxide and the formation of some kind of sugar—possibly glucose ($C_6H_{12}O_6$), possibly *canose* ($C_{12}H_{22}O_{11}$)—in the chlorophyll corpuscles. Allusion was made to this some pages back, where it was pointed out that the cells containing chlorophyll—which are always near the surface of the plant—absorb carbon dioxide from the atmosphere or water (the latter in the case of submerged plants), and that this gaseous compound is decomposed in the chlorophyll corpuscles under the action of light. It was also stated that the first organic compound as a result of the process is, in most plants, a form of sugar.† The importance of the leaves in the economy of Vegetable Life will at once be seen, when it is added that these are the organs chiefly concerned in the work in question.

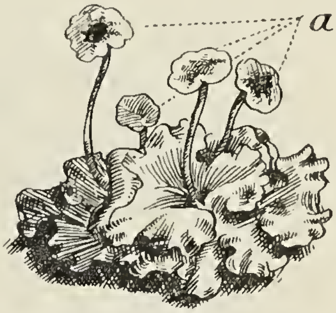

Fig. 91.—Thallus of a Liverwort. (*a*) Antheridial receptacles.

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* *On the Growth of Plants in Closed Cases*, etc., pp. 10, 11.

† It has been proposed to apply the term *photosynthesis* instead of *assimilation* to this process. "As the activity of the chlorophyll apparatus is so essentially dependent upon light," says Dr. Reynolds Green, "the process of construction of carbo-hydrate substances from carbon dioxide and water, which is its primary object, may appropriately be called *photosynthesis*. This term has certain advantages over the older expression, the *assimilation of carbon dioxide*, as the term 'assimilation' may preferably be reserved for the process of the incorporation of the food materials into the substance of the protoplasm" (*Introd. to Veg. Phys.* 1900).

You may illustrate the process by a simple experiment. Let the stem of any pond-weed of convenient size be placed in water which holds carbon dioxide in solution (a little spring water will be pretty sure to contain a sufficiency for the purpose), and exposed to sunshine. What follows? From the cut surface of the stem, bubbles of gas are given off at regular intervals. The liberated bubbles consist of oxygen. Probably you now perceive what has taken place. Some of the carbon dioxide has been absorbed by the leaves of the plant, and there decomposed, under the influence of light, the oxygen having been given back to the water as useless. This setting-free or evolution of oxygen from plants is popularly known as "breathing" or respiration, but the term, in this application of it, is altogether erroneous, the process being one of exhalation and simple evaporation. Plants *do* respire, just as animals respire,* but the giving off of oxygen in the manner described is not respiration. *We have been watching one of the consequences of assimilation.*

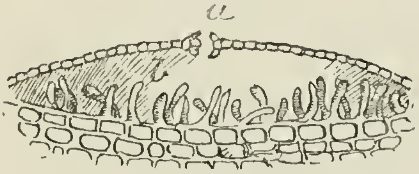

Fig. 92.—Vertical section of a portion of the thallus of *Marchantia polymorpha*, showing a single stomata pore (*a*), and air chamber (*b*).

Mark, we say, "consequences." The true act of assimilation—in this case the appropriation of carbon—has taken place out of sight in the leaves, which, as already stated, are the organs chiefly concerned in this important function. The process itself is only imperfectly understood, though enough has been discovered to stimulate inquiry. Undoubtedly the first stage in the building-up process is the union of CO_2 and H_2O to form the starting-point for a carbo-hydrate; and the first carbo-hydrate which can be detected in the leaves is, as we have been pointing out, some form of sugar. The leaves are chemical laboratories, wherein the little green corpuscles of protoplasmic matter produce results that have baffled our Kölligers and Faradays, though every year the Plant World is yielding up fresh secrets to the patient workers of to-day. The exceeding difficulty of the investigation may be gathered from a remark by Mrs. Somerville, that "although it may be inferred that chemical action is the same within the vegetable as it is in the inorganic world, yet it is accomplished within the plant under the control of the occult principle of plant life."†

Under certain conditions cells and tissues containing chlorophyll have their power of assimilation arrested for a time, though the cells continue to respire. Dr. A. J. Ewart has made an extensive series of experiments on various plants bearing upon this point (see *Journal of the Linnean Society*, vol. xxxi. pp. 364–461). The agents or circumstances producing this inhibition are stated by him to be "dry heat, moist heat, cold, desiccation, partial asphyxiation, etherisation, treatment with acids, alkalies, and antipyrin, accumulation of the carbo-hydrate products of assimilation, immersed in very strong plasmolytic solution, and prolonged insolation. The inability to assimilate is, if the cell remain living, only temporary, being followed sooner or later by a more or less complete recovery of the power of assimilation."

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* That is, by giving out carbon dioxide and watery vapour and inhaling oxygen. A plant placed in *pure* carbon dioxide would soon be suffocated, just as would an animal.

† *Molecular and Microscopic Science*, vol. i. p. 168.

In the leaves are manufactured the starch-grains, proteids, etc., of which some account has been already given, and which are required, not only for the present growth of the plant, but also as reserve food material. But these substances are solid and insoluble in water, a circumstance which prevents their passage from cell to cell; and they have therefore to undergo further changes before they are dismissed from the leaves. Starch, for example ($C_6H_{10}O_5$), is converted, by means of a ferment called *diastase*, into the soluble substance sugar* ($C_6H_{12}O_6$), which, becoming part of the assimilated nutrient sap, is distributed through the plant, to be again fixed in the form of starch at particular places, as in the grains of cereals, the tubers of the Potato, etc. The proteids are also changed, the agents in their transformation (known as *proteolytic enzymes*) being pepsin and the various trypsins.

But we spoke of *respiration*. What is it? If the term is a misnomer as applied to the evolution of oxygen from plants, in what does true respiration consist? The question may be answered by a simple experiment. Soak in water for twenty-four hours, to induce germination, a quantity of peas, then place them in a jar, disposed in single layers between pieces of moist blotting-paper. The mouth of the jar is closed by a tightly fitting cork, which is withdrawn after an interval of a few hours. Now take a lighted taper and plunge it into the vessel. Instantly the flame is extinguished. You guess the cause? While confined in the jar the peas have been evolving carbon dioxide, and in carbon dioxide no flame will live. That the vessel is charged with this gas may be proved in a simple manner. Into another jar pour some lime-water. When carbon dioxide and lime-water are brought together, the former combines with the lime and forms an insoluble carbonate of lime, which imparts a white cloudy appearance to the liquid. If, then, we next tilt the jar containing the peas over the other vessel, the carbon dioxide, which is heavier than the air, will be poured into the lime-water, and the result just described will be witnessed.

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* *I.e.*, glucose or grape-sugar. The formula for cane-sugar, sometimes called sucrose, is $C_{12}H_{22}O_{11}$.

It would be easy to demonstrate further that the germinating peas have absorbed a volume of oxygen nearly equal to the volume of carbon dioxide given out; indeed, the absorption has really preceded the evolution of the latter, and is the cause of it. In other words, the oxygen has found its way into the living cells of the peas, and by decomposing, with the active assistance of the protoplasm, some of the complex carbon-containing compounds, has liberated the carbon dioxide. What is known as *oxidation*, a burning of organic material, has taken place—the very process which goes on in animal bodies, and which is called respiration. The germinating peas have, in fact, been breathing, not through any special respiratory organs, as is the case in animals, but breathing nevertheless; and what is true of the subjects of our experiment is true of the living parts of almost all plants. Respiration is as necessary to vegetable as it is to animal life, and in both the great kingdoms breathing and living may be taken as synonymous terms. True, in certain of the lower forms of vegetation, such as the Yeast-plant (*Saccharomyces Cerevisiæ*) and Bacteria (*Schizomycetes*), a process of fermentation goes on which appears to obviate the necessity for respiration; but the exceptions only give emphasis to the rule. In the *Algæ* and Mosses (*Musci*), again, respiration is comparatively feeble; still, *they breathe*, and whenever a free supply of atmospheric oxygen is denied, they are suffocated and die.

As we ascend the scale of Life, respiration becomes more and more vigorous, and is often attended by a sensible *liberation of heat*, particularly in certain parts of the plant and at certain periods. For this reason the *Soldanellas*, a small genus of pretty Alpine plants, are able to melt a way through the hardest crust of snow, their slender flower-stalks pushing upwards to the light and air as effectually as if they were so many fire-heated awls. Ruskin has very beautifully alluded to this phenomenon in his description of these nurslings of the snow in *Modern Painters*: "If, passing to the edge of a sheet of it upon the lower Alps, early in May, we find, as we are nearly sure to find, two or three little round openings pierced in it, and through them, emergent, a slender, pensive, fragile flower (*Soldanella alpina*), whose small dark purple-fringed bell hangs down and shudders on the icy cleft that it has cloven, as if partly wondering at its own recent grave, and partly dying of very fatigue after its hard-won victory; we shall be, as we ought to be, moved by a totally different impression of loveliness from that which we receive among the dead ice and the idle clouds: there is now uttered to us a call for sympathy, now offered to us an image of moral purpose and achievement, which, however unconscious or senseless the creature may indeed be that seems so to call, cannot be heard without affection, nor contemplated without worship, by any of us whose heart is rightly turned, or whose mind is clearly and surely sighted." In a footnote to this passage, which is quoted at length in *Frondes Agrestes*, the same eloquent interpreter of Nature states his belief that *Soldanella alpina* is the only Alpine flower which actually pierces snow, though he has seen Gentians filling thawed hoof-prints. "Crocuses are languid till they have had sun for a day or two. But the Soldanella enjoys its snow at first, and afterwards its fields."

We may add, before passing from this subject, that in many—probably in *all*—flowers there is a distinct rise of temperature at the period of opening, a fact the truth of which may be demonstrated by a thermometer in the case of inverted tubular and bell-shaped flowers, the air in which is not only warmed, but, being little disturbed by the surrounding atmosphere, retains its warmth. Kerner (*Natural History of Plants*) has recorded the results of some experiments in this direction which are very interesting. The temperature inside the spathe of one of the Brazilian Aroids, the handsome large-leaved *Monstera deliciosa*, was found to be 38° when the temperature of the outer air was only 25°; the spathe of another Aroid, *Arum cordifolium*, was 35—39° at the same air temperature; while *Arum italicum*, a plant extremely common in the region of the Mediterranean flora, closely resembling our British Cuckoo-pint, actually exhibited a temperature of 44° when the thermometer in the external air only registered 15°. This was at the period of the opening of the spathe, which was noticed at the time to give forth a peculiar fragrance, like wine. Here, then, we have a plant the temperature of whose respiring flowers exceeds that of blood-heat!

The *evolution of light* from plants is also thought to be connected more or less remotely with respiration—*i.e.*, with the combustion of carbon compounds in living cells. Many theories, however, have been advanced to account for the phenomena of luminosity, and the paucity of our knowledge on the subject may be gathered from the fact that the very existence of the phenomena—at least, in the higher plants—is to this day gravely questioned by many botanists. In our opinion the evidence in favour of the alleged occurrences is too accumulative to be resisted; though doubtless they are due to other causes than those which produce the phosphorescence in plants of lower organisation, as we hope presently to show.

The great naturalist Linnæus was the first—at least in modern times—to record an observation on the subject, his attention having been drawn to it by his daughter, Christina Linnè. Walking in her father's garden one hot June evening, she observed the flowers of *Tropæolum majus* (the Garden Nasturtium) give forth sparks or flashes. The phenomenon was repeated on successive evenings, and also in the mornings before sunrise, when not only her father, but other men of science were present. One of these gentlemen, a well-known electrician named Wilcke, believed the flashes to be electric; and this appears to be the opinion of most writers who have investigated the subject since; though some believe that the scintillations are only apparent, and class them among optical illusions. The fact that the flashes are invariably observed at times when the air is dry and charged with electricity, is, however, an argument —and a pretty strong one—in favour of the former view.

Perhaps no flowers exhibit this phenomenon in a more remarkable degree than those of the plant noticed by Linnæus; though the Common Marigold (*Calendula vulgaris*), African Marigold (*Tagetes erecta*), Martagon Lily (*Lilium Martagon*), and Sunflower (*Helianthus*) are also highly luminous. Erasmus Darwin, in his *Loves of the Plants*, has chosen the Nasturtium as the typical phosphorescent plant:—

> Ere the bright star, which leads the morning sky,
> Hangs o'er the blushing east his diamond eye,
> The chaste Tropæo leaves her secret bed;
> A saint-like glory trembles round her head:
>
> * * * * * *
>
> O'er her fair form the electric lustre plays,
> And cold she moves amid the lambent blaze.
> So shines the glow-fly when the sun retires,
> And gems the night air with phosphoric fires.

The remarkable scintillations first observed by Christina Linnè have now been witnessed by so many credible and competent observers, that it is singular their reality should be longer doubted. M. Haggren, a Swedish naturalist, observed them frequently, and when at work in his garden employed a man to watch the flowers and to make signals whenever the flashes occurred. They both saw the light constantly, and at the same moment, playing round the flower-heads of the Marigold. This was in the months of July and August, the phosphorescence being only seen at sunset or for half an hour after, and never on rainy days or when the air was loaded with vapours. A microscopic examination of some of the flowers, to discover whether some small insects or phosphoric worms might not be the cause of the light, soon convinced our naturalist that such a theory was untenable. Nothing of the kind was found, and he came to the conclusion that the flashes were electric. His own theory, however, that the electric light was caused by the pollen of the florets, which in flying off was scattered upon the petals, is hardly to be taken seriously.

In the year 1835 Mr. J. R. Trimmer, of Brentford, was an eye-witness of the phenomenon, of which he sent an account to the *Magazine of*

The chaste Tropæo leaves her secret bed;
A saint-like glory trembles round her head.
—*The Loves of the Plants*, canto iv.

Botany. In this case, also, everything points to electricity as the exciting cause. The writer was walking in his garden in the evening, where many Nasturtiums were in bloom, his thoughts far away from the subject of phosphorescence, when vivid flashes from those flowers attracted his notice. The flashes were the most brilliant he had ever observed, and at the same time—a fact to be specially remarked—*the sky was overcast with a thunder-cloud.*

Seven years later (August 4th, 1842) the phenomenon was observed by a Mr. Dowden and three others, at nearly the same time of the day and under similar climatic conditions. In other words, the flashes were seen at about eight o'clock in the evening, after a week of dry weather. "By shading off the declining daylight, a gold-coloured lambent light appeared to play from petal to petal of the flowers, so as to make a more or less interrupted corona round the disc." The flowers examined were a double variety of the Common Marigold.

Even in quite recent years more than one naturalist has recorded his personal observations of the phenomenon. Thus Canon Russell, writing to *Science Gossip* in September, 1891, says: "On the evening of June 16th, 1889, I happened to be taking a stroll round the rectory garden, and passing by a fine plant of the Common Double Marigold, of a deep orange colour, I was struck by a peculiar brightness in the appearance of the flowers. After watching for a few seconds, I observed, to my great surprise, that corruscations of light, like mimic lightning, were playing over the petals. Thinking that I might be only the victim of an ocular illusion, I brought out other members of the household, and asked them to report exactly what they saw. Some perceived the flashes readily enough, but others only slowly and after patient observation, all eyes not being equally sensitive to such rapid vibrations of light. These performances commenced about 8.30 p.m., and continued for perhaps an hour. I afterwards ascertained that much later on, when it was almost dark, the whole plant seemed to glow with a sort of pulsing phosphorescence."

The Common Nasturtium was also luminous in a less degree, the luminosity in this case extending to the leaves, which, it is further stated, gave off "a blue vapour of extreme tenuity." "I put a leaf of Nasturtium on the stage of a microscope," continues the canon, "and, having focussed it for the central spot from which the nerves branch off, under an inch and a half objective, I brought it into a room nearly dark. Looking at it then through the microscope, I found that the leaf could be distinctly seen almost by its own light. The appearance of the luminous vapour floating over its surface (like moonlight over rippling water) was strikingly beautiful. The whole leaf seemed to twinkle with points of light—the main ribs radiating from the common centre shining out like a silver star. These effects are best witnessed after a day of hot sunshine."

Canon Russell's discovery of phosphorescence in the leaves of *Tropæolum* introduces a new feature into the inquiry, and is of much interest. Moreover, the fact that the luminosity remained in or on a leaf which had been detached from the plant and removed to quite a different spot, and that it was visible alike in daylight, dusk, and lamplight, surely disposes once and for ever of the optical illusion theory; for how could such a theory be sustained in view of the *persistence* of the phenomenon?

Thus far all the flowers noticed have been of an orange colour, and it is probable that such flowers are phosphorescent in an exceptional degree, a circumstance with which the poet Coleridge was evidently familiar. It was he who wrote:—

> 'Tis said at Summer's evening hour,
> Flashes the golden-coloured flower,
> A fair electric flame.

But the phenomenon is by no means restricted to "golden-coloured" flowers. Mr. Trimmer observed it not only in *Tropæolum*, but also in the White Rose (*Rosa alba*), Scarlet Geranium (*Pelargonium inquinans*), and a white species of *Œnothera* (*Œ. grandiflora* [*v. concolor*]); and a correspondent of the *Gardener's Chronicle* for October, 1843, testifies to having frequently observed the luminous appearance in the Hairy Red Poppy (*? Papaver pilosum*). To this list may be added the Scarlet Verbena (*V. chamædrifolia*), concerning the phosphorescence of which a very interesting letter appeared in the same journal for July, 1859. "We witnessed this evening (June 10th, 1858), a little before nine o'clock," says the writer, "a very curious phenomenon. There are three Scarlet Verbenas, each about nine inches high, and about a foot apart, planted in front of the greenhouse. As I was standing a few yards from them and looking at them, my attention was arrested by faint flashes of light passing backwards and forwards from one plant to the other. I immediately called the gardener and several members of my family, who all witnessed the extraordinary sight, which lasted for about a quarter of an hour, gradually becoming fainter, till at last it ceased altogether. There was a smoky appearance after each flash, which we all particularly remarked. The ground under the plants was very dry; the air was sultry and seemed charged with electricity. The flashes had the exact appearance of summer lightning in miniature." On subsequent occasions the phenomenon was again witnessed—always in the hot dry weather, and about the time of sunset.

The False Dittany (*Dictamnus Fraxinella*)—of which there are several garden varieties, white, red, and purple—may be said to occupy an unique place among luminous plants (fig. 93). To quote once more from Erasmus Darwin:—

> What time the eve her gauze pellucid spreads
> O'er the dim flowers, and veils the misty meads,
> Slow o'er the twilight sands or leafy walks,
> With gloomy dignity Dictamna stalks;
> In sulphurous eddies round the weird dame
> Plays the light gas, or kindles into flame.

In plain prose, the plant secretes a fragrant essential oil in great abundance; and in warm weather this exudes and volatilises, so that the air becomes impregnated with it, and is rendered not only very fragrant, but also highly inflammable; insomuch that, if a naked flame be brought near the plant, the oily vapour takes fire. This discovery, like that of the luminosity of *Tropæolum*, was made by the gifted daughter of Linnæus, and has been since verified by Dr. Hahn, the result of whose investigations is given in the *Journal of Botany* for 1863. His first experiments were unsuccessful, but on bringing a lighted match to a nearly faded blossom, he saw "a reddish, crackling, strongly shooting flame, which left a powerful aromatic smell, and did not injure the peduncle." Since then he has repeated the experiment several times, and a careful microscopic examination of the plant has shown that the inflammable etheric oil is contained in numerous minute reddish brown glands, located in the flower-stalks.

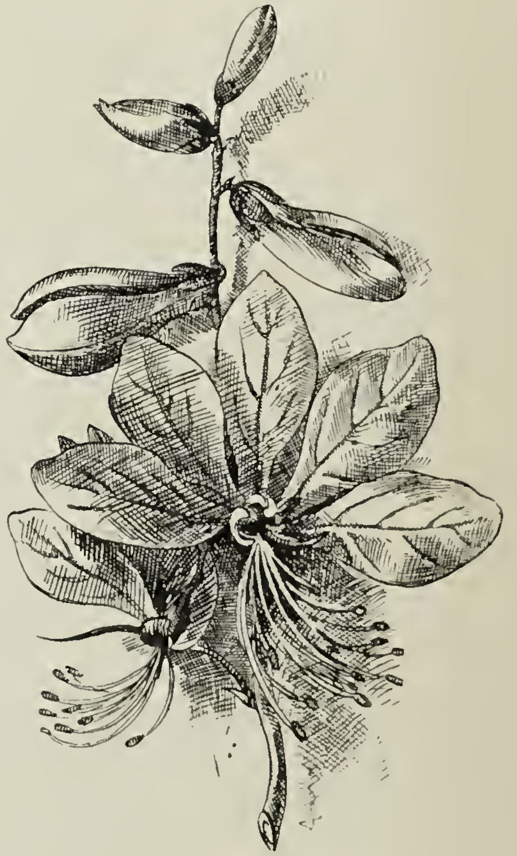

Fig. 93.—*Dictamnus Fraxinella.*

Other instances of luminosity in Flowering Plants—which, however, must be more quickly passed over—are afforded by the latex or milk-sap of a species of Euphorbia (*E. phosphorea*), which is said to shine with a phosphorescent light on warm nights in the ancient forests of Brazil, and by the roots of certain plants, as the fragrant Khus-khus (*Andropogon*) and

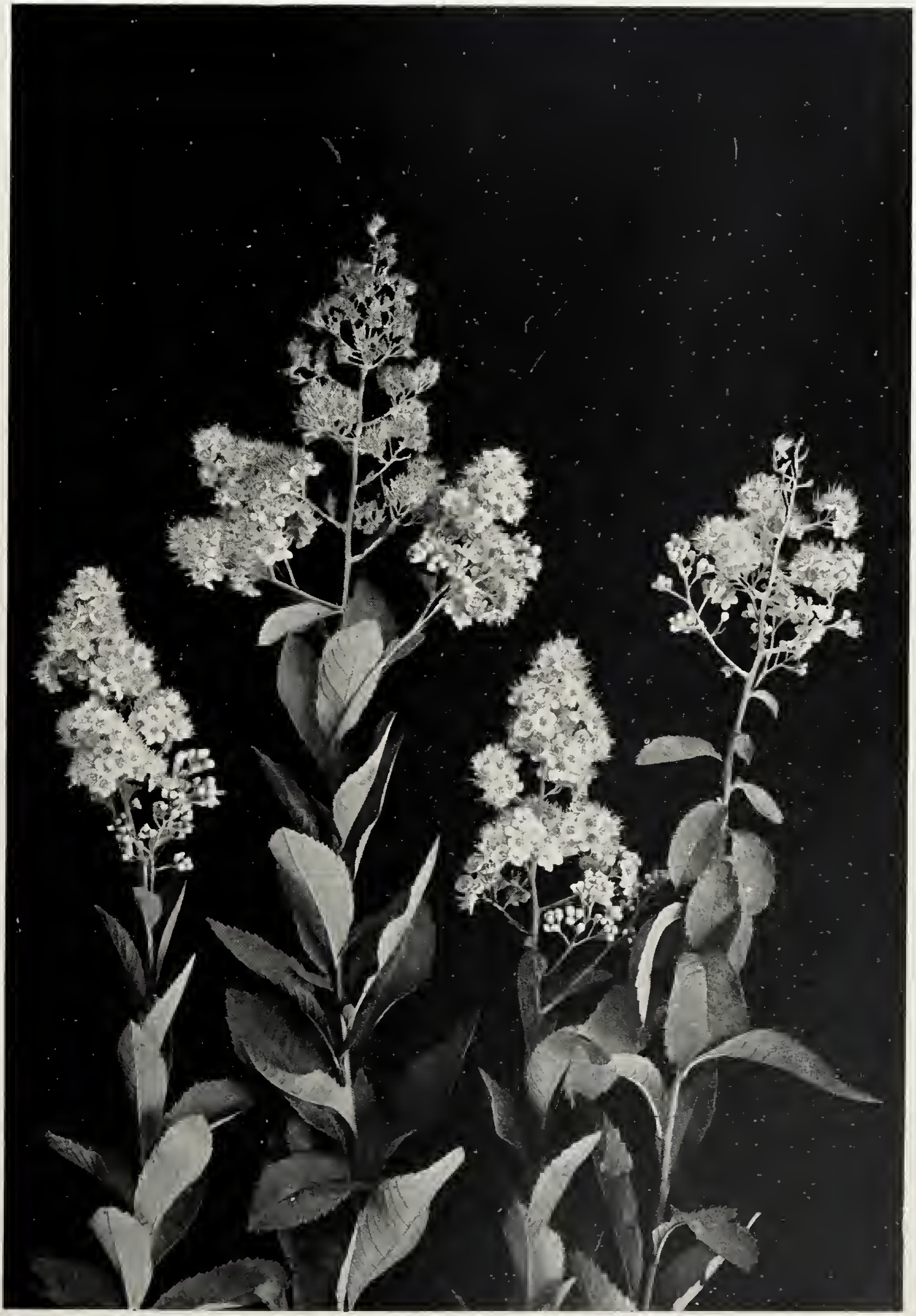

Photo by Henry Troth.

MEADOWSWEET (*Spiræa Ulmaria*).

A favourite plant of pollen-seeking insects, which often cross-fertilise the flowers whilst engaged in collecting the yellow meal.

PLATE III.

other grasses. A luminous rootstock referred to in the *Proceedings of the Royal Asiatic Society* for April, 1845, is perhaps that of the Khus-khus grass. After a wet cloth had been applied to its surface for an hour or two it gleamed in the dark "with all the vividness of a glow-worm"; and though the lustre faded away as the specimen dried, it was revived on the application of fresh moisture, nor did it appear to lose its luminous property after frequent applications. The sap of the Cipo, a South American Vine, is said to be so highly luminous that, when injured, it seems to bleed streams of living fire. "Large animals have been noticed standing among its crushed and broken tendrils, dripping with the gleaming fluid, and surrounded by a seeming network of fire."

Passing now from the Flowering Plants, we come to the non-flowering or Cryptogamic, to which the Mosses, Seaweeds, Fungi, etc., belong. Here we meet with some very striking and unmistakable instances of luminosity, though in some of these, doubtless, the phenomenon is connected rather with the process of assimilation than with electrical conditions of the atmosphere. We have seen that assimilation commences with the decomposition of carbon dioxide in the chlorophyll corpuscles, and that this takes place under the action of light. Light is therefore absolutely essential to the successful discharge of the functions which are carried on in green tissues; and hence the very interesting adaptations for increasing light intensity in plants which grow in caverns and grottoes and in the twilight depths of the sea.

Certain caves of Central Europe have long been celebrated for their luminous Mosses. On entering one of these caves, the eye is at once attracted to the floor of the chamber, which gleams and sparkles with minute points of golden-green light. The ignorant beholder might imagine that he had stumbled upon a store of hidden emeralds, but any hopes of sudden enrichment fostered by such a thought will be quickly dissipated; for the treasure is only gnome's treasure at best. On bringing the supposed prize to the light, it is found to consist of nothing but lustreless earth and yellowish grey fragments of stone, dotted over with tiny, dull green, feather-like Moss-plants (fig. 94), as well as with multitudes of delicate branching threads, which are simply more Moss-plants, but in an earlier stage of development. It is from these slender filaments—or, rather, from the spherical and microscopic cells at the ends of their branches—that these deceptive and beautiful scintillations arise. In fact, the little semi-transparent globes, each of which contains a few grains of chlorophyll, act like the lenses of a cat's eye, refracting the scanty incident light where it strikes the globes, and producing a bright disc on each as the result (fig. 95). By this means the light is concentrated on those places where the chlorophyll is situated, and, in spite of the surrounding gloom, the granules are able to discharge their special functions in an entirely efficient manner. The name of this very curious luminous Moss is *Schistostega osmundacea.*

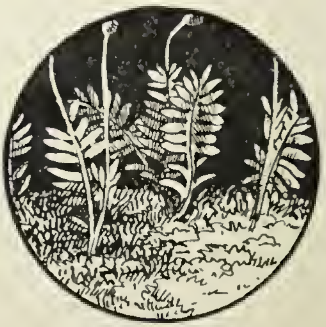

Fig. 94.—Second and perfect stage of luminous Moss.

There are other Mosses (*e.g.*, *Hookeria splendens*) which exhibit the same phenomenon, though in a less marked degree; nor are these special organisations confined to the *Musci.* They are to be found in many of the Sea-wracks and other submarine plants; though the deep-sea Algæ are more often distinguished by an optical phenomenon of another kind. The popular idea that as you descend deeper and deeper into the ocean, and the light of day vanishes, a fiery yellow first succeeds, then a flaming red (the "watery sea-hell" of Schleiden), then dark crimsons and purples, and finally an impenetrable black, is partially, though not entirely, correct; and the circumstance has an important bearing on our present inquiry. Strictly speaking, the colour of sea-water—in reflected as well as in direct light, and at all depths where the light can reach it—is blue, a fact which is scientifically accounted for by the high refrangibility of blue rays, which enables them to pass easily through the water, while the red, orange, and yellow rays, which are far less refrangible, are absorbed. Yet red and yellow rays are absolutely essential to plants containing chlorophyll if carbo-hydrates are to be formed and life and growth maintained;[*] and the question naturally arises, How do the deep-sea *Algæ*, which are deprived of all but the blue rays, compensate themselves for this deprivation? The answer to the question affords a striking instance of the resourcefulness of Nature. No marine plants inhabit a deeper zone than the *Florideæ* or Red Seaweeds (fig. 96), and it is by means of the pigment which gives them that colour that the deficiency is remedied. This pigment, which is known as *phyco-erythrin* (Greek *phukos*, seaweed; *eruthros*, red), is fluorescent in a high degree, and has the remarkable property of changing the blue rays which visit the plant into yellow, orange, and red ones; so that the chlorophyll granules contained in the underlying tissues are enabled to carry on their functions in a regular manner, decomposing carbon dioxide and forming

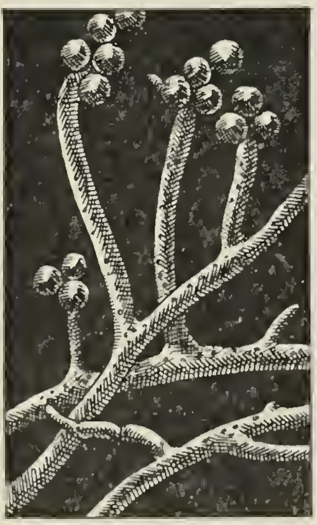

Fig. 95. — Thread-like growth (protonema) of luminous Moss. Greatly magnified.

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[*] The blue rays are said to be actually destructive of vegetable protoplasm.

organic substances just as do the green *Algæ* which float upon the surface of the water. In fact, the arrangement is quite as perfect and efficient as is the lens arrangement in luminous Mosses.

Below the level of the deep-sea *Florideæ* no plant life exists, so that they may be said to mark the sunset of marine vegetation. Where these flourish the darkling ocean is aglow with colour—rose-pink, carmine, purple, russet-brown—a glory of swaying fronds and tangled branching stems; the nearest approach to the "fiery yellow" and "flaming red" of Schleiden's watery hell; yet descend but a little farther, and no vestige of this weird beauty remains. Darkness and death supply the place of the Mars-like vegetation. It is the region of perpetual night in the Plant World.

We come now to the *Fungi*. Here we meet at once with examples of luminosity which are undoubtedly due to phosphorescence. Phosphorescent Fungi are abundant, for instance, in the coal-mines of Dresden, where they are even said to be dazzling to the eye. Hanging in festoons and pendants from the uneven roofs, twisting root-like round the pillars and covering the walls, they give to these otherwise dreary excavations the semblance of fairy palaces. "I saw the luminous plants here in wonderful beauty," says Mr. Erdman, a commissioner of mines, "and the impression produced by the spectacle I shall never forget. It appeared, on descending into the mine, as if we were entering an enchanted castle. The abundance of those plants was so great, that the roof and the walls and pillars were entirely covered with them, and the beautiful light they cast around almost dazzled the eye. The light they give out is like faint moonshine, so that two persons near each other could readily distinguish their bodies."

These spreading masses of luminous vegetable matter were formerly looked upon as a distinct species of Fungus, and were classed with a few others of similar root-like form in the group *Rhizomorpha*; but they are now known to be simply the *mycelia* of various species of *Agaricus*, the large genus to which our common edible Mushroom belongs. The phosphorescence is said to be due to slow decay and oxidation, either in the mycelia or fructification of the Fungi; and Sir Joseph Hooker found that alcohol, heat, and dryness soon dissipate it.

Fig. 96. — *Delesseria sanguinea*: one of the Red Seaweeds.

That eminent botanist frequently saw the luminous mycelia in the dead wood used for fuel by the natives of Northern India, and has furnished some remarks on the subject in his interesting and informing *Himalayan Journals.* "The phenomenon," he writes, "is most conspicuous on stacks of firewood. At Darjeeling, during the damp, warm summer months (May to October), at elevations of 5,000 to 8,000 feet, it may be witnessed every night by penetrating a few yards into the forest —at least, it was so in 1848 and 1849; and during my stay there billets of decayed wood were repeatedly sent to me by residents, with inquiries as to the cause of their luminosity. It is no exaggeration to say that one does not need to move from the fireside to see this phenomenon, for if there is a partially decayed log amongst the firewood, it is almost sure to glow with a pale phosphoric light. A stack of firewood, connected near my host's (Mr. Hodgson's) cottage, presented a beautiful spectacle for two months (in July and August), and on passing it at night, I had to quiet my pony, who was always alarmed by it. The phenomenon invariably accompanied decay, and is common on oak, laurel, birch, and probably other timbers; it equally appears on cut wood and on stumps, but is most frequent on branches lying close to the ground in the wet forests. I have reason to believe that it spreads with great rapidity from old surfaces to freshly cut ones. That it is a vital phenomenon, and due to the mycelium of a Fungus, I do not in the least doubt, for I have observed it occasionally circumscribed by those black lines which are so often seen to bound mycelia on dead wood, and to precede a more rapid decay."

Agaricus olearius, a Fungus common in the South of France, is also highly luminous. It grows in the dark crevices of the Olive-stems in November and December, when the gills under the pileus or cap are said to shine as brightly as a glow-worm. Equally remarkable is the Brazilian species of phosphorescent *Agaricus* (*A. Gardneri*) (see page 99)—a parasite on the Pintado Palm—the light of which is of a pale greenish hue, and equals in brilliancy that of the larger fire-flies; while Borneo can boast a closely allied species, also parasitical on trees, the greenish luminous glow of which has been likened to the glow of the electric discharge. Australia appears to be exceptionally rich in these fairy lamps, most of which belong to the same great genus, *Agaricus*, though the prevailing colour of their light is white. One species, found by Drummond in the valley of the Swan River, deserves particular mention, if only on account of its size and weight. It measured sixteen inches in diameter and a foot in height, and weighed about five pounds. A ponderous lamp for the fairies, this! Our traveller hung the Fungus up inside the chimney of his sitting-room to dry, and on passing through the apartment in the dark, observed that it gave out a most remarkable light, such as he had never seen described in any book. No light could have been whiter;

Luminous Fungi in a Brazilian Forest

and "the luminous property continued, though gradually diminishing, for four or five nights, when it ceased on the plant becoming dry." When some natives saw it, they cried out "Chinga!"—their name for a spirit—and seemed afraid of it. Both this traveller and another (Mr. Hugh Low) have affirmed that the light from certain of these Agarics is bright enough to read by. Even these statements, however, are eclipsed by the account of the spruce log which the Rev. M. J. Berkeley saw, and which was literally ablaze on the inside with the white mycelia of some unidentified species of *Myxogaster*.* When some of the luminous matter was "wrapped in five folds of paper,' the light penetrated through all the folds on either side as brightly as if the specimen was exposed," albeit the luminosity had been already going on for three days!

M. Tulasne, who made some careful experiments in vegetable phosphorescence, found that the light from luminous Fungi was extinguished in vacuo or non-respirable gases, and from this he inferred that "it is due to a slow combustion without heat, arising from a chemical combination of the oxygen of the atmosphere, inhaled by the Fungus, with a substance peculiar to the plant." Kerner, who agrees with this view, makes the following helpful observations on the subject. "There are certain organic substances which shine in alkaline solutions when oxygen is present. It seems natural to suppose that such materials are formed in the Agarics mentioned [*Gardneri*, *igneus*, *noctilucens*, and *olearius*], and that oxygen is conveyed to them in respiration, thus producing the phenomena of light. At any rate, this would be the simplest way of explaining the luminosity. As to the advantage accruing to the plant itself, we can only form surmises. It seems most probable that the Fungus-flies and beetles which deposit their eggs in the mycelia and fructification of *Hymenomycetes*, and which are connected with the distribution of their spores . . . are thereby guided to the Fungi in the dark of night. Many of these flies and beetles only fly at night, and, like so many winged nocturnal animals, direct their path towards a luminous object" (*Natural History of Plants*).

Whether this is the true explanation of the phenomenon, we do not pretend to say, and those who may desire to pursue their inquiries on the subject will do well to consult the learned paper by M. Tulasne in *Ann. des Sci. Nat.* (1848), or Dr. Phipson's little book on *Phosphorescence*, in which much curious information has been brought together. Nevertheless, we think it has been pretty clearly demonstrated that luminosity in the *lower* plants is connected almost exclusively with one or other of those two important functions, assimilation and respiration—the former

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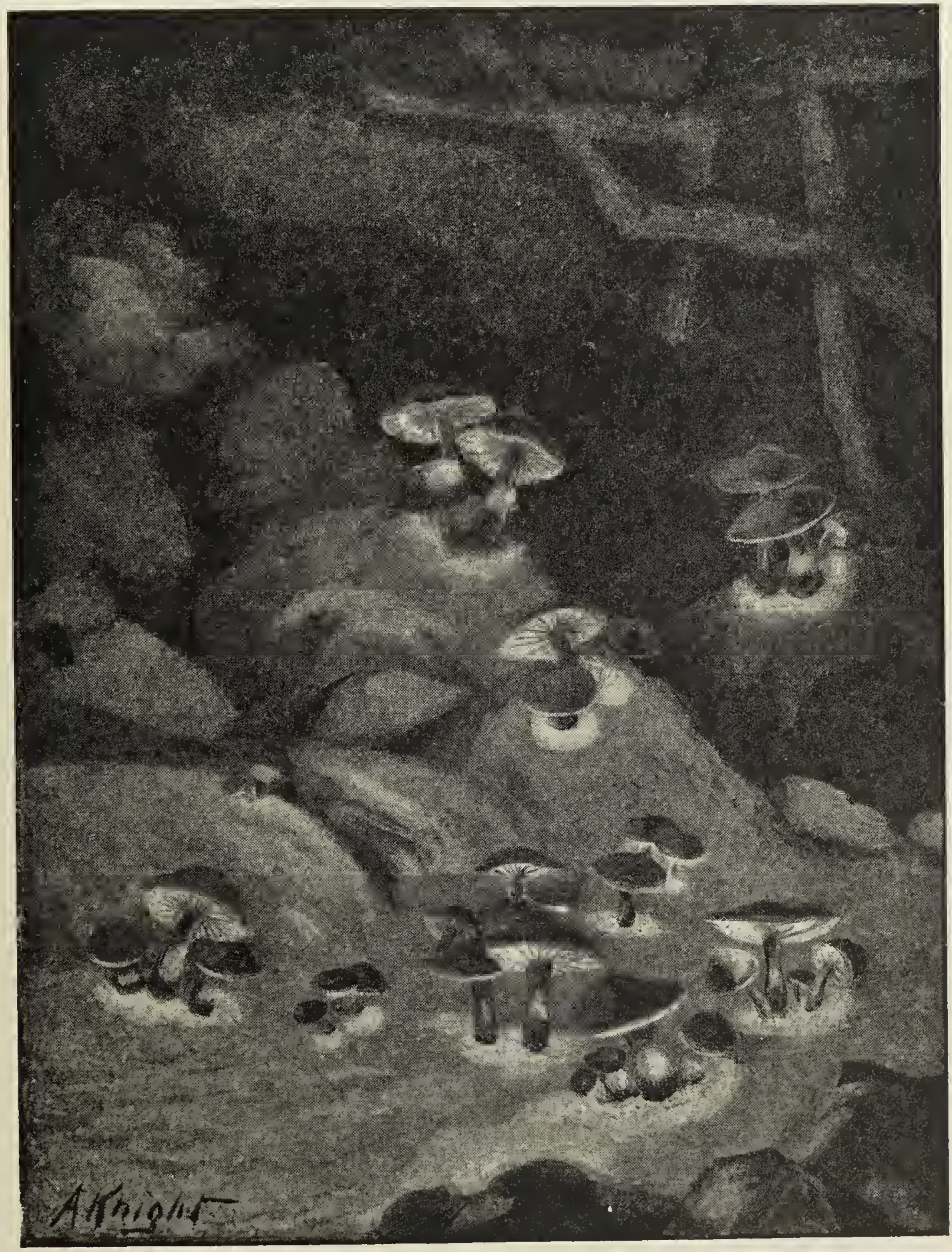
* The Myxogasters appear as small incrustations on dead leaves and twigs, and vary in colour from black to bright orange. They form an anomalous group of Fungi.



Some Luminous Agarics.

in the case of cave-growing Mosses and deep-sea *Algæ*; the latter in the case of certain Fungi which lodge their spores in decaying wood; whereas the luminosity which has been observed in the *higher* plants, and which appears to be confined to white, yellow, orange, and scarlet flowers, is presumably due to electrical conditions of the atmosphere, and, in that case, it ought perhaps to be classed among abnormal phenomena.

But it is time to conclude this long digression, and to return to our more immediate subject—the sap of plants.

The true sap, which conveys the elaborated food material from the leaves to the root, etc., is very different from the crude, thin, watery sap which ascends from the root to the leaves. A curious fact, illustrative of this difference, is, that the latter is nearly or quite harmless in those plants whose proper juices have the most virulent properties. Thus, according to Carpenter, "the inhabitants of the Canary Islands draw off the ascending sap, which serves as a refreshing drink, from the interior of the stem of *Euphorbia canariensis*, a tree of which the descending sap is of a very acrid nature, resembling that of the Common Spurge (*E. Peplus*) of this country, but much more powerful." It is important to bear this distinction clearly in mind. The crude sap ascends, as we have seen, chiefly by way of the wood elements of the vascular system; while the elaborated sap, avoiding the wood elements, passes down the sieve-tubes, the cellular tissues of the bark,* and, possibly, the laticiferous vessels, though it is now a question whether the latter play an important part as distributors.

Thus we have an ascending and a descending, a crude and an elaborated sap, and each pursuing independent routes through quite distinct parts of the plant. When the experiment has been tried of removing a ring of bark from a tree—say, an Oak or Elm (fig. 97)—growth *below* the ring has almost immediately ceased, conclusively showing that the flow of assimilated nutrient sap to that part of the stem has also ceased, and therefore that the way of the sap's descent is the bark. A branch of an ordinary fruit-tree may be made to bear specially fine fruit simply by binding it tightly with a ring of stout wire; for by this means the downward flow of elaborated sap is checked, and the fruit gets the benefit of all the food produced by the leaves of the branch. The fact is well known to gardeners, and much of the prize fruit shown at exhibitions is produced in this way. The upward flow of crude sap of course goes on without interruption through the uninjured wood-vessels; and thus the leaves above the ring are duly supplied with raw material from the soil, out of which to elaborate new descending sap.

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* The elaborated sap containing the *nitrogenous* organic substances (*i.e.*, the soluble results of proteid conversion) descends by way of the sieve-tubes, and, *perhaps*, the laticiferous vessels, while that containing the *non-nitrogenous* organic substances (sugar, etc.) passes downwards through the parenchyma.

Plants which have neither leaves nor roots are of course unable either to draw up a supply of crude sap or to elaborate the juices required to sustain life. They therefore resort to nefarious practices, and live, like the feudal barons in the days of King Stephen, by plundering their neighbours. Of this sort are the Dodders (*Cuscuta*), the Broom-rapes (*Orobanche*), the Balanophorales, the Rafflesiales, and a great many more of the plants so well named *parasites.* We will say nothing of the Mistletoe (*Viscum album*), which is, comparatively speaking, a mild offender, and, moreover, possesses true leaves (fig. 98). The germination of the Dodder (fig. 99) is effected, like that of plants in general, in the earth, and without requiring the presence of other plants. The embryo (fig. 100)—which, unlike the embryos of most Flowering Plants, has no *external* reserve of food material to feed upon—is nourished, in its first development, at the expense of the albuminous matter *within itself.* The slender and elementary root pushes its way into the earth, and the young, red, thread-like stem rises above it. If it finds no other living plant near it, it dies; but should it succeed in finding one, it surrounds the stem, and from the points of contact proceed suckers which contain conducting tissue, and this tissue attaches itself to the conducting tissue of the host, and sucks the juices which the host has elaborated. Then the root of the Dodder becomes obliterated and dies, and henceforth the plant lives by its suckers alone. "Whilst it was not a parasite," says the eminent French botanist De Candolle, "it rose vertically; as soon as it became one, it was no longer tempted to direct itself either vertically or towards the light. Its shoots dart from one plant to another, and thus are conveyed to new victims when the old ones are exhausted. Often the seeds germinate before they quit the capsules, and the new plant immediately becomes a parasite; this is particularly observed in the *Cuscuta monogyna*, which attacks the Vines in Languedoc." *

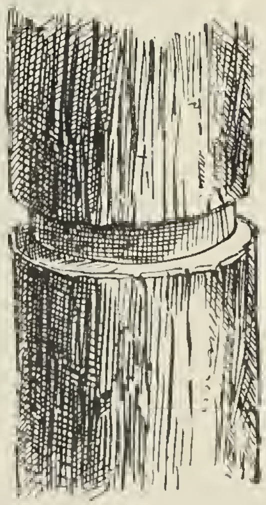

Fig. 97.—Young trunk of Elm with ring of bark removed.

Fig. 99 shows the Greater Dodder (*C. europea*), which Gerarde describes as "a strange herbe, altogether without leaves or roote, like unto threds, very much snarled or wrapped together confusedly, winding itselfe about bushes and hedges, and sundrie kindes of herbes." This species is very partial to the Hop-plant (*Humulus*). Other species attack the Flax-plant, Clover, Thyme, and Furze or Gorse (*Linum usitatissimum*, *Trifolium*, *Thymus*, *Ulex europæus*).

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* *Cyclopædia of Natural History*, vol. ii. p. 262.

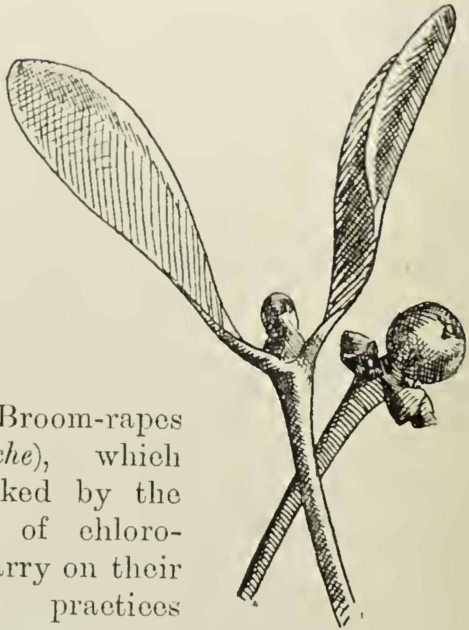

Fig. 98. — Leaves buds, and fruit of Mistletoe.

In the meek garb of modest worth disguised,
The eye averted and the smile chastised,
With sly approach they spread their dangerous charms,
And round their victim wind their wiry arms.

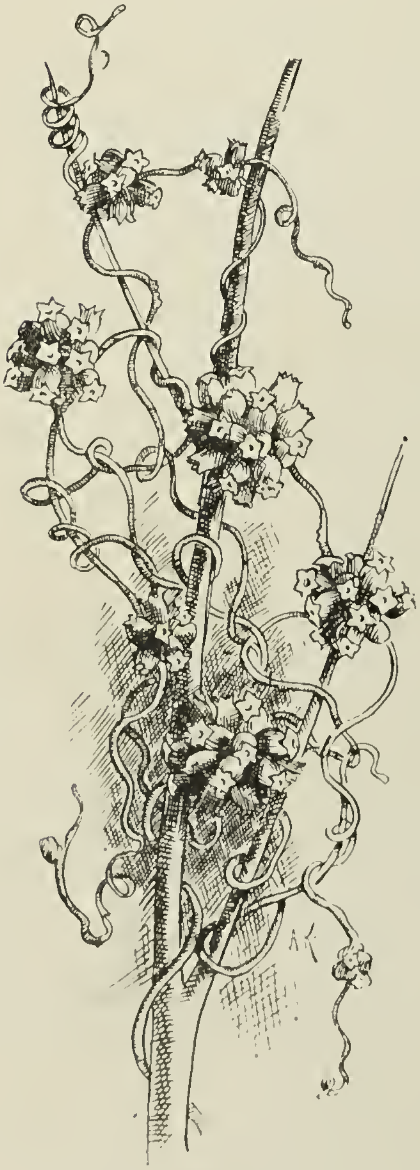

Fig. 99.—Greater Dodder

The Broom-rapes (*Orobanche*), which are marked by the absence of chlorophyll, carry on their thievish practices underground by fastening on the roots of trees and shrubs, so that when they rise above the soil, and put forth their spikes of dingy flowers, only the instructed botanist would suspect them of the crimes which lie at their door. The Balanophorales and Rafflesiales, which embrace some seven or eight families, are also destitute of chlorophyll, and support themselves in much the same way as the Broom-rapes, by becoming parasitic on the roots of green-leaved woody plants. They belong chiefly to the tropical parts of Asia and America; but a few species are found in South Africa, and two or three belong to Australia and the Mediterranean area. The last-named group (the Rafflesiales) includes that vegetable wonder, *Rafflesia Arnoldi*, the largest flower in the world, of which we must give some account (fig. 101).

The plant was discovered about eighty years ago by Dr. Arnold, a botanist of some note, while exploring with Sir Stamford Raffles's party in the interior of the island of Sumatra. The news of the discovery was conveyed by Dr. Arnold in a letter to an unknown friend, and it will be better to quote from his account than to give the facts in words of our own. The doctor says: "Here [at Pulo Lebbas, on the Manna river, two days' journey inland of Manna], I rejoice to tell you, I happened to meet with what I regard as the greatest prodigy of the vegetable world. I had ventured some way from the party, when one of the Malay servants came running to me with wonder in his eyes, and said: 'Come with me, sir, come! A flower—very large—beautiful—wonderful!' I immediately went with the man about a hundred yards into the jungle, and he pointed to a flower growing close to the ground, under the bushes, which was truly astonishing. My first impulse was to cut it up and carry it to the hut. I therefore seized the Malay's parang (a sort of instrument like a woodman's chopping hook), and finding that the flower sprang from a small root which ran horizontally (about as large as two fingers or a little more), I soon detached it, and removed it to our hut. To tell you the truth, had I been alone, and had there been no witnesses, I should, I think, have been fearful of mentioning the dimensions of this flower, so much does it exceed every flower I have ever seen or heard of; but I had Sir

Fig. 100. — Embryo of Greater Dodder.

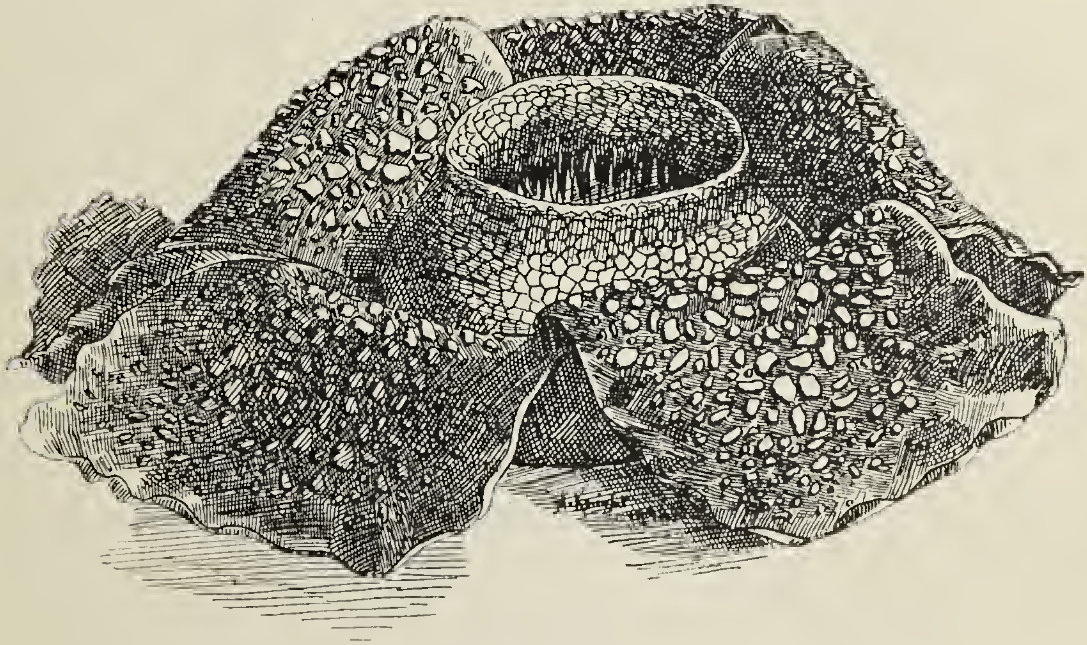

Fig. 101.—*Rafflesia Arnoldi:* the largest known flower. Fig. reduced.

Stamford and Lady Raffles with me, and a Mr. Palsgrave, a respectable man, resident at Manna, who, though all of them equally astonished with myself, yet are able to testify as to the truth.

"The whole flower was of a very thick substance, the petals and nectary being in but few places less than a quarter of an inch thick, and in some places three-quarters of an inch; the substance of it was very succulent. When I first saw it, swarms of flies were hovering over the mouth of the nectary, and apparently laying their eggs in the substance of it. It had precisely the smell of tainted beef. The calyx consisted of several roundish, dark brown, concave leaves, which seemed to be indefinite in number, and were unequal in size. There were five petals* attached to the nectary, which were thick, and covered with protuberances of a yellowish white, varying in size, the interstices being of a brick-red colour. . . . Now for the dimensions, which are the most astonishing part of the flower. It measures a full yard across, the petals being twelve inches from the base to the apex, and the space between the insertion of one petal and the opposite one being about a foot. Sir Stamford, Lady Raffles, and myself took immediate measures to be accurate in this respect, by pinning four large sheets of paper together, and cutting them to the precise size of the flower. The nectarium [or hollow central bowl of the flower] would, in the opinion of all of us, hold twelve pints, and the weight of this prodigy we calculated to be fifteen pounds." The plant grows parasitically on the roots of a species of Vine (*Vitis*), and consists, besides this remarkable flower, of a mycelium-like tissue.

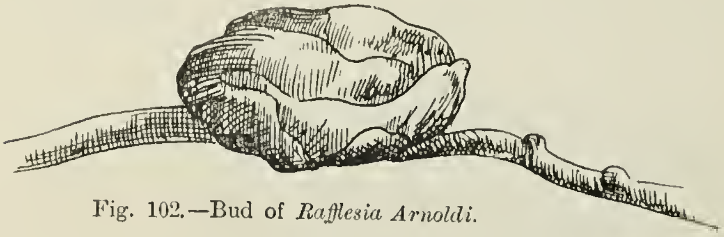
Fig. 102.—Bud of *Rafflesia Arnoldi*.

The Cuscutas and the Orobanches, the Balanophorales and the Rafflesiales, by no means exhaust the list of vegetable parasites. There are the Fungi, that comprehensive group in which are included not only most of the mildews, rusts, smuts, blights, etc., whose pernicious ways are unpleasantly familiar to farmers, nurserymen, and fruit-growers, but also that singular genus the *Cordyceps*, several species of which are parasitical upon insects, spiders, and their allies. Fig. 103 shows a West Indian *Cordyceps* (*C. sphecocephala*), which attacks a species of *Polistes* or wasp. The wasps may frequently be seen flying about with plants of their own length projecting from their bodies. Other well-known species of the same family are *Cordyceps entomorrhiza* and *militaris*, which sow themselves in—and derive their nourishment from—the bodies of larvæ or pupæ buried in the soil or among dead leaves. "These Fungi," says Professor Trail, "may be regarded as beneficial to gardeners, inasmuch as they destroy insects, many of which feed on garden produce. They are not often met with, however, and can scarcely be regarded as of much importance from this point of view." A New Zealand species, *C. Robertsii*, popularly known as the "Vegetable Caterpillar," sometimes reaches a height of eight inches.

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* Petals and calyx would be more appropriately considered together under the collective name of perianth.

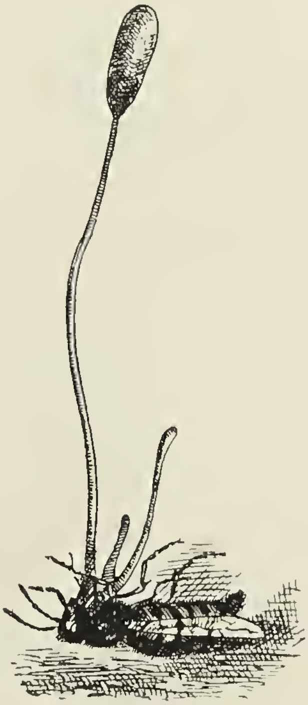
Fig. 103. — *Cordyceps sphecocephala*, a North American species of parasitical Fungus.

In reviewing the ground traversed in this and the preceding chapter, we think it will be conceded that the analogy between the economy of the Vegetable and a well-regulated household (see p. 67) has been sufficiently established. We have observed the admirable manner in which the multitudinous cells and vessels perform their allotted functions in the general scheme, and the harmony of action which exists between the several parts. We have seen how certain organs pump up the required water, and others carry it; how some are employed in getting rid of the waste, while others elaborate the nutrient material, and others, again, distribute the elaborated food through the plant, or store up the superfluity for future use. These functions (such is the superiority of Nature's handiwork) are performed surely, silently, unobtrusively; with the exquisite precision, though without the din and dirt and oily nidor of a piece of man-wrought mechanism.

Such, in brief, is the economy of the Plant. We have but touched the fringe of the subject; but what a subject it is! How vast and inexhaustible! How incomprehensible and fathomless! How abounding with witness of a present God!

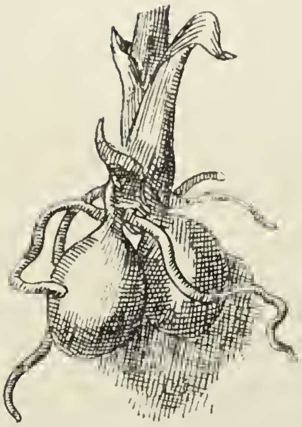

Fig. 160.—Purple orchis root.

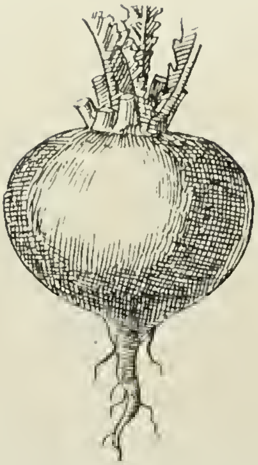

Fig. 151.—Napiform root—a Turnip.

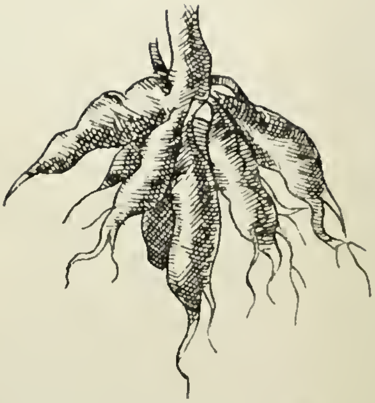

Fig. 159.—Tuberous fascicular root.

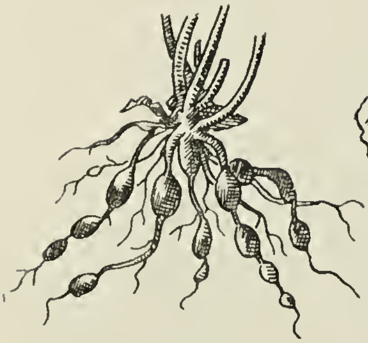

Fig. 156.—Moniliform root.

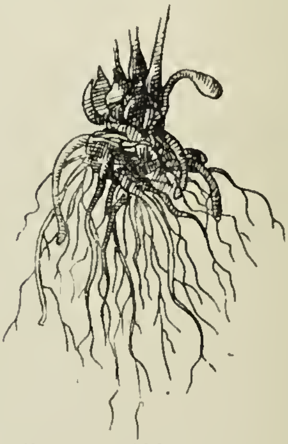

Fig. 154.—Fibrous root.

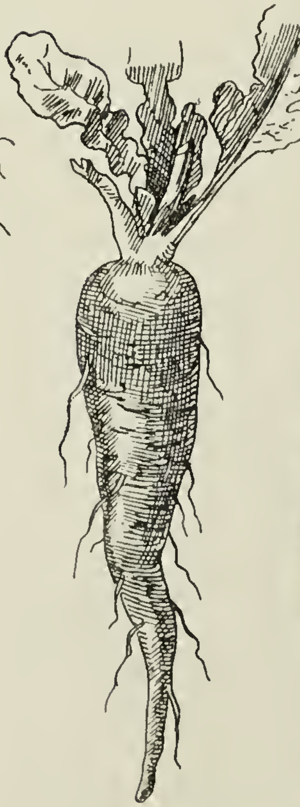

Fig. 150.—Carrot—a much thickened tap-root.

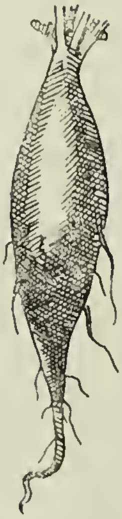

Fig. 152.—Radish—a fusiform root.

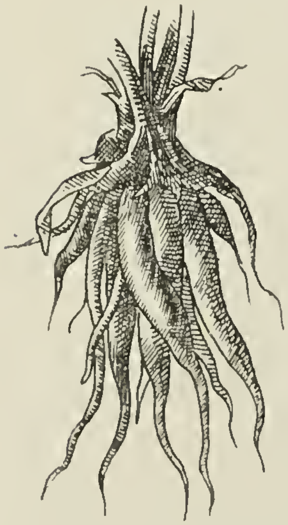

Fig. 155.—Tuberous root.

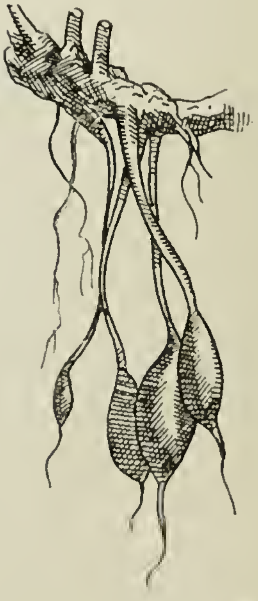

Fig. 157.—Nodulose root of Dropwort

Some Forms of Roots (*vide* pp. 125-127).

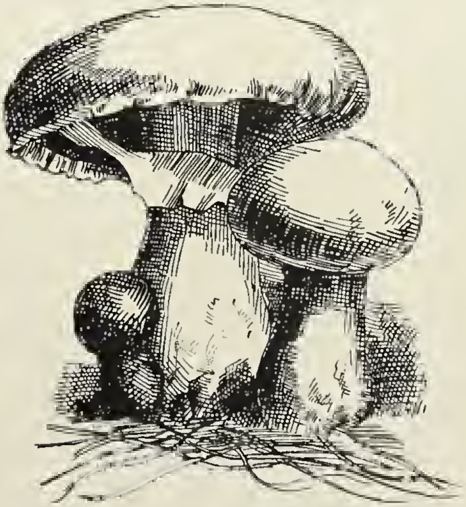

Fig. 104.—Common Mushroom.

CHAPTER VI

SEED AND ROOT

Then rise the tender germs, upstarting quick
And spreading wide their spongy lobes, at first
Pale, wan, and livid; but assuming soon,
If fanned by balmy and nutritious air,*
A vivid green. COWPER.

"THE nature of everything," says Lord Bacon, "is best considered in the seed"—an aphorism which contains a truth of very wide application, though it is only quoted here because the first part of our subject is the seeds of plants. That the nature of the *Plant* is best seen in the seed is a truism which perhaps every physiologist would be willing to admit, and we shall probably be as ready to make a similar admission after weighing a few of the facts with which it is proposed immediately to deal.

When the reign of the Frost-spirit is over, and the earth is brought once more under the mild and vivifying influence of the spring, a large proportion of the seeds confided to the ground, either recently or at the end of the preceding autumn, swell, and release from their envelopes the precious germs which they have held in ward during the intervening months, and which, endowed with a life of their own,

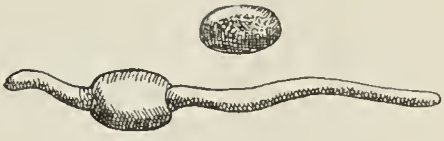

Fig. 105.—Spore and germinating spore of Edible Fungus (*Morchella esculenta*).

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* The poet might have added, "And fostered by the light-dispensing sun."

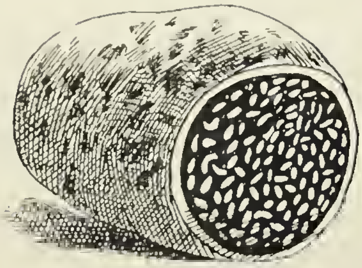


Fig. 106.—Section of a *Scleroderma.*

soon imbibe freely their nutriment from the atmosphere and the soil. Such is, in essence, the phenomenon of germination, the simplicity of which is perhaps not less wonderful than the results achieved are manifold and surprising. We say "in essence," for when we come to consider the phenomenon in detail, a surprising variety confronts us. Let us consider a few examples.

The majority of Fungi are propagated by minute dust-like *spores,* which differ from seeds in containing no embryo or young plant, but simply a tiny mass of living matter. Kick a ripe puff-ball—the dusty powder that flies out consists of hundreds of these spores. Or if we select as our type the Common Mushroom (*Agaricus campestris,* fig. 104), the spores are borne on the under side of the frail umbrella-like cap (the *pileus*) on minute stalks. A powerful microscope is needed to examine them, as individually they are quite invisible to the naked eye. When these spores fall to the ground they begin to swell, and presently put out cellular threads of wonderful tenuity, which grow and branch, and continue growing and branching, till they form a beautiful white flocculent mass — the "Mushroom spawn" of our markets—from which new Mushrooms may be raised. Thus the spore does not develop at once into a perfect Mushroom, with thick stem and spreading disc-shaped fructification; there are two distinct stages of development. The close pile of whitish threads —botanically known as the *mycelium*—appears first; and then, out of the mycelium, arises the fructification or Mushroom, consisting of stalk and cap. It is important to bear these successive stages

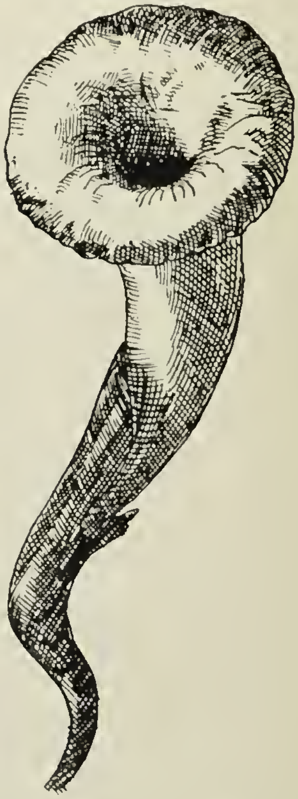


Fig. 107.—*Polyporus Rostkovii:* found growing on willow-wood in a cellar.

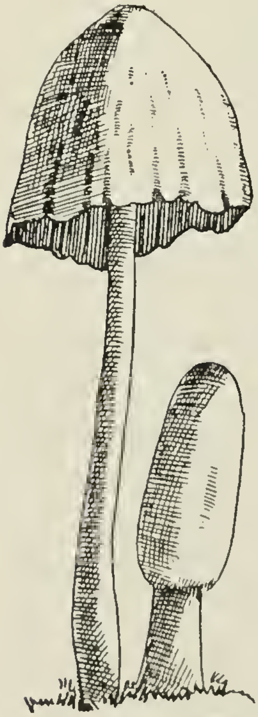


Fig. 108.—*Coprinus atramentarius.*

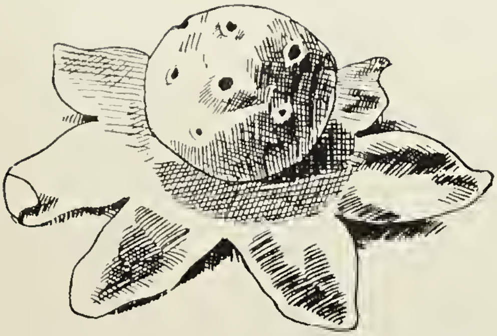


Fig. 109.—*Geaster coliformis:* found near Haarlem.

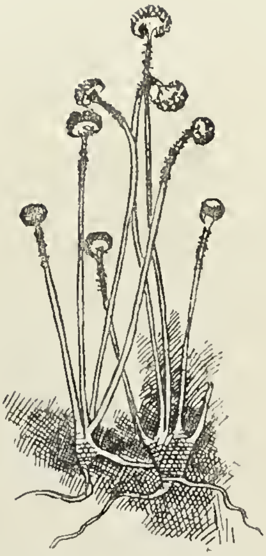


Fig. 110.—*Ascophora mucedo:* the "green mould" of bread and of other substances prepared from flour (greatly magnified).

of development in mind.

When demolishing old houses, one frequently finds on the damp rafters or underneath the planks the mycelia of other Fungi, spreading from a centre nearly equally in all directions, and so delicate that a breath might dissipate them; but in the species common in woods and meadows, it is the fructification alone which attracts our notice. In the latter case, indeed, the mycelia are for the most part hidden, either in the soil or in the barks of trees; while the fruit-bearing organs assume the brightest colours, and flaunt themselves among the wild-flowers with gay effrontery. They appear in all conceivable forms (figs. 106-118), graceful and grotesque, elaborate and simple, geometrical and irregular. You may meet with them as cups and bottles, as horns and trumpets, as umbrellas and canopies, as finger-rings and strings of beads, as eggs and egg-cups, as globes and discs, as solid leathery lumps and hollow spherical cages; and the wonder excited by this inexhaustible variety of forms is not lessened when we remember that the beginning of each was a tiny spore, smaller than the dust-motes that gyrate in the sun. Gazing at these curious plants, one almost catches the enthusiasm of the poet Woodhouse, who sings (we quote from memory):—

Lovelier far than vernal flowers,
The Mushrooms shooting after showers;
That fear no more the fatal scythe,
But proudly spread their bonnets blithe,
With coverings formed of silk and snow,
And lined with brightening pink below.

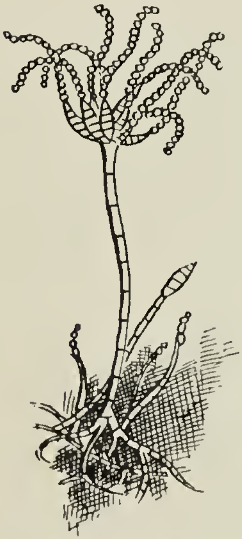


Fig. 111.—*Penicillium verticillatum:* one of the moulds (greatly magnified).

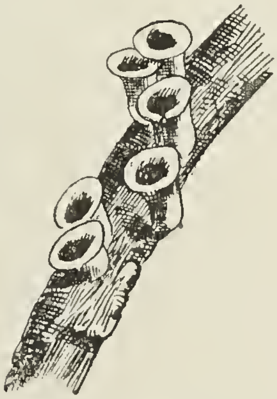


Fig. 112.—*Crucibulum vulgare* from New Zealand.

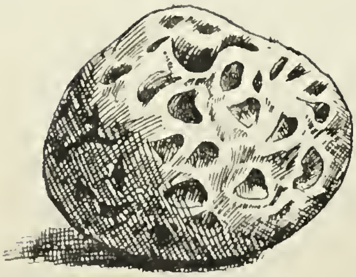


Fig. 113.—*Cyttaria Darwinii* from Tierra del Fuego.

But more the *later* Fungus race
Whose forms the mellowing wood-
lands grace.
Their tapering stems, robust and
light,
Like columns catch the searching
sight;
Like fair umbrellas furled or
spread,
Each lifts its many-coloured head,
Grey, purple, yellow, scarlet,
brown,
Shaped like War's shield, or Pre-
late's crown,
Like Freedom's cap, or Friar's cowl,
Or China's bright inverted bowl.

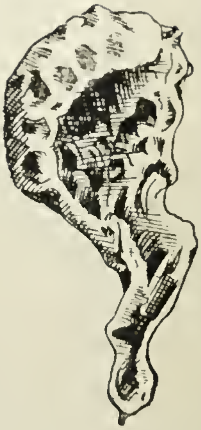


Fig. 114.—Another specimen of *Cyttaria Darwinii* in section.

With this brief glance at the development of a Fungus spore, let us take a forward step, and consider, with equal brevity, the round of life in one of the Mosses. The Mosses (*Musci*) contain chlorophyll, and therefore occupy a more important position in the Vegetable World than the Fungi; they form, indeed, a sort of link between the higher and lower plants. When one of the microscopic spores ejected by an adult Moss-plant has fallen into congenial soil, and begins to germinate, its innermost coat (for it is double-coated) protrudes, and develops into thread-like branching filaments (the *protonema*) recalling the mycelia of Fungi, but distinguished from mycelia by containing chlorophyll in their cells (fig. 119). From these filaments arise the leafy shoots of the new, but not yet perfect Moss-plant, which is botanically known as an *oophyte* (*i.e.*, egg-plant); and this, when fully developed, produces the male and female organs of the plant—the *antheridium* and *archegonium*, as they are called—on the successful discharge of whose functions future fructification depends. In fact, the antheridium is filled with myriads of minute spiral bodies (somewhat analogous to the pollen of flowers), which it ejects upon

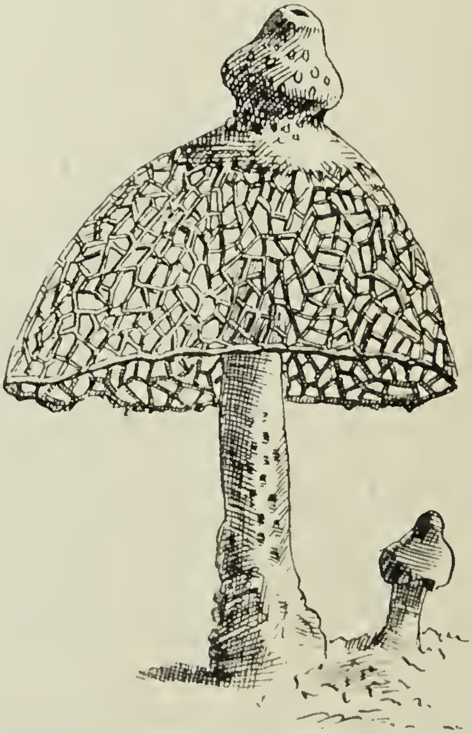


Fig. 115.—*Dictyophora phalloidea*, an Indian fungus in which the spores are carried by flies.

the archegone, and so brings about fertilisation (figs. 120-122). As a result of this process, we get the full-grown Moss-plant, with its urns and hoods (*sporangia* and *calyptræ*), as shown in the drawing (figs. 123, 124); the urns being full of new spores—the life-germs of a future generation.

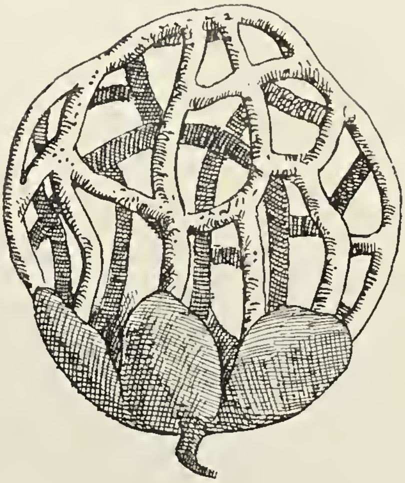


Fig. 117.—*Clathrus cancellatus:* one of the Stinkhorn Fungi.

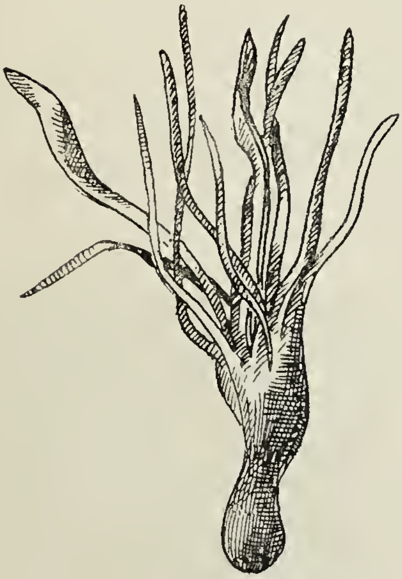


Fig. 116.—*Clavaria fusiformis:* drawn from a specimen found at Epping.

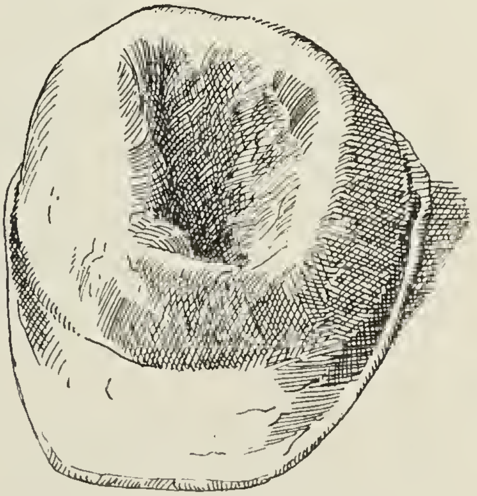


Fig. 118.—Travelling cap made from a species of fungus.

Do not think that the simple Moss-plants are undeserving of your notice. They will well reward the most reverent and painstaking study—indeed, few objects are so fraught with interest, whether to the microscopist or the outdoor naturalist. I know the remark is often made, in tones of careless disparagement: "They are only Mosses!" But he who speaks thus lightly has no true sense of the beautiful, and certainly can never have taken the trouble to examine these delicate organisms. Ruskin's touching tribute to their lowly ways and tender beauty, which forms one of the choicest passages in *Modern Painters*, might be commended to all such, and we offer no apology for quoting the famous passage: "Meek creatures!" he calls them, "the first mercy of the earth, veiling with hushed softness its dintless rocks; creatures full of pity, covering with strange and tender honour the scarred disgrace of ruin, laying quiet finger on the trembling stones to teach them rest. No words, that I know of, will say what these Mosses

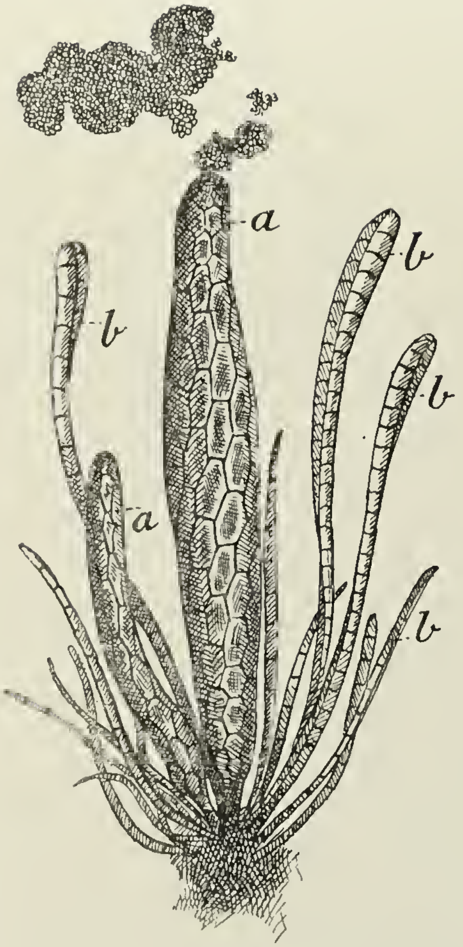


Fig. 119.—Hair Moss (*Polytrichum commune*). (*a a*) Antheridia. (*b b*) Hairs and sterile filaments (paraphyses).

are. None are delicate enough, none perfect enough, none rich enough. How is one to tell of the furred and rounded bosses of beaming green—the starred divisions of rubied bloom, fine-filmed, as if the rock-spirits could spin porphyry as we do glass—the traceries of intricate silver, the fingers of amber, lustrous, arborescent, burnished through every fibre into fitful brightness and glossy traverses of silken change, yet all subdued and passive, and framed for simplest, sweetest offices of grace? They will not be gathered, like the flowers, for chaplet or love-token; but of these the wild bird will make its nest, and the wearied child his pillow. And as the earth's first mercy, so they are its last gift to us; when all other service is in vain, from plant and tree, the soft Mosses and grey Lichen take up their watch by the headstone. The woods, the blossoms, the gift-bearing grasses, have done their part for a time; but these do service for ever. Trees for the builder's yard, flowers for the bride's chamber, corn for the granary, moss for the grave."

A still higher scale of Vegetable Life is reached in the Ferns. The spores of ferns are contained in a capsule or *sporange* (fig. 125), dense clusters of which form, when ripe, those brownish patches

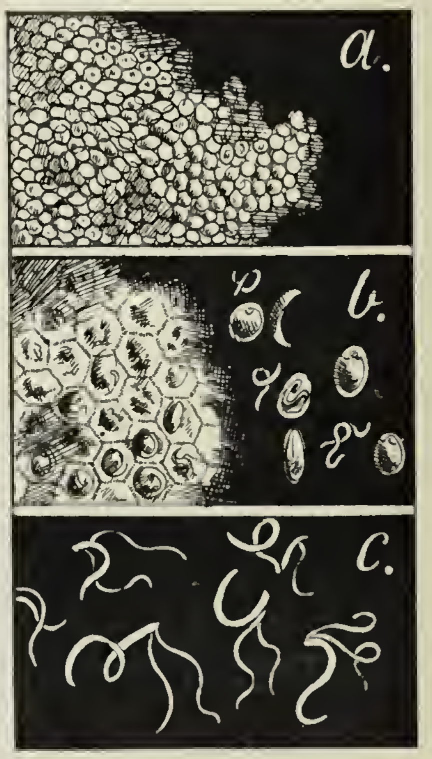


Fig. 120.—*Polytrichum commune.* (*a*) Cellular contents of antheridium. (*b*) The same mature and discharge the antherozoids. (*c*) Antherozoid.

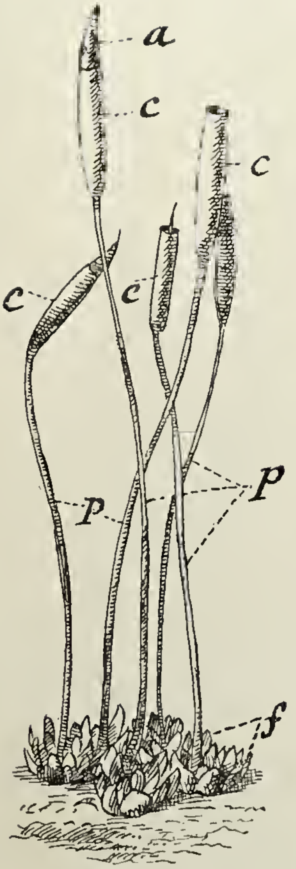


Fig. 121. — Some Moss-plants. (*f*) Leaves. (*p*) Seta. (*c*) Capsules. (*a*) Calyptra.

or incrustations on the under sides of the fronds, familiarly known as the "fructification," botanically as *sori*. Each of the brown patches is, in fact, a *sorus*, and consists of a dense cluster of *sporangia*, or spore-containing vessels (fig. 126). When the spores have escaped from these vessels, and begin to germinate in the moist earth, they do not put forth delicate filaments like the Fungi and Mosses, but each produces a small green leafy expansion, which is known as the *prothallus* (fig. 127). From the under side of the prothallus, slender root-hairs are given off; and along with these, the *antheridia* and *archegonia*—minute organs of reproduction, homologous with, though simpler in structure than, those of Mosses. It is only when fertilisation has taken place that the egg develops into a new Fern-plant.

Thus far we have confined ourselves to spores, which are the chief means of multiplication in the lower plants, and which, as already pointed out, contain no young plant or embryo. Spore-plants have no evident flowers, and their organs of fructification were obscure to the early botanists, on which account they were called *Cryptogams*, or Hidden-marriage plants, from the Greek *kruptos*, hidden, and *gamos*, marriage. They form, indeed, one of the two great sub-kingdoms into which all plants are divided; the other sub-kingdom comprising the Seed-plants or *Phanerogams* (Greek *phaneros*, evident, and *gamos*). To the Spore-plants or Cryptogams belong the Protophytes (unicellular forms of vegetable life, whether containing chlorophyll or not), *Algæ*, *Fungi*, Liverworts, Mosses, Ferns, Horsetails, Club-mosses, Water-ferns, and Selaginellas; and to these we shall revert at greater length in a later chapter; the Seed-plants or Phanerogams embrace all the rest.

Bearing in mind what has been said about spores, let us now observe the process of germination in true seeds. On planting a grain of Barley in suitable soil, the first change to be noticed is the swelling of the grain, and this is

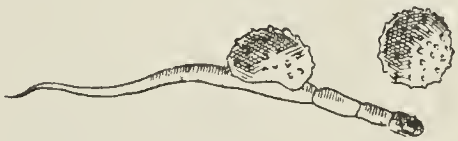


Fig. 122.—Spore and germinating spore of a Moss-plant (*Gymnostomum ovatum*).

followed before very long by the appearance of a root—the *primary root*—and several independent root-fibres (fig. 128), the former dying before it has grown to any length. The stem, which originates in what is known as the *plumule*, appears later. The plumule is a bud consisting of several leaves on a reduced axis, and its outer sheath, in which the rest of the plumule is still enclosed, emerges first. Meanwhile, the root-fibres (which are really *adventitious roots* proceeding from the base of the plumule) continue to grow, taking a downward direction, while the stem begins to force its way towards the light and sun. *Why* the stem should take an upward course, contrary to the force of gravity, is not known, but the fact is interesting. Our ignorance of the ultimate causes of many other occurrences quite as common is not less complete. Why are fluids incapable of resisting a change of shape? We cannot tell. Why does the earth

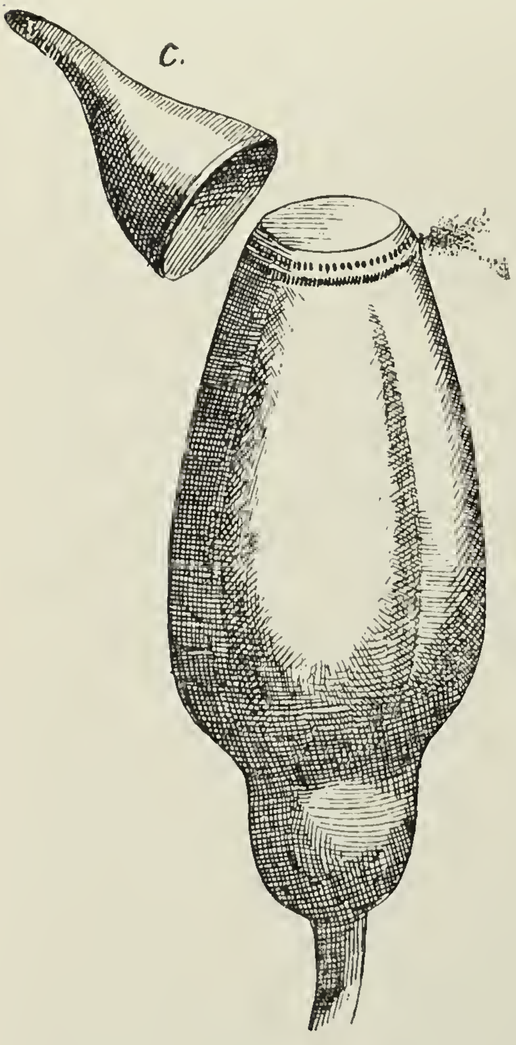


Fig. 123.—Fructification of a Moss-plant (*Polytrichum gracile*). (c) Calyptra.

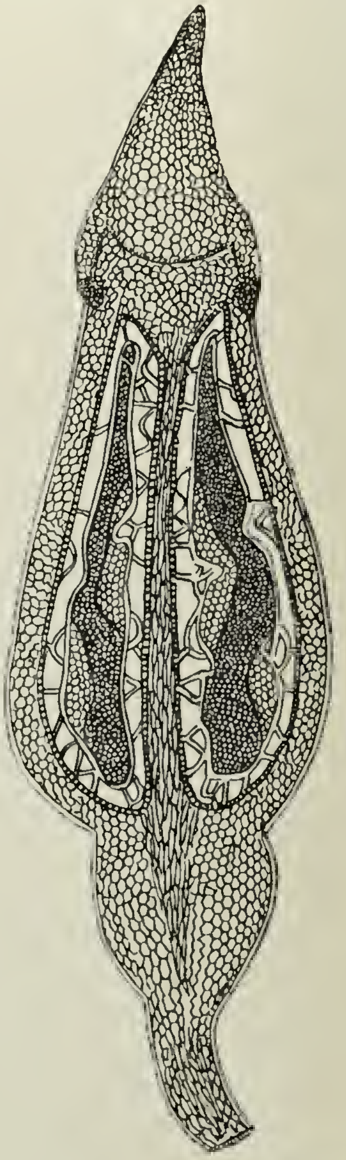


Fig. 124.—The same in section, showing the two *loculi*, or spaces, filled with spores.

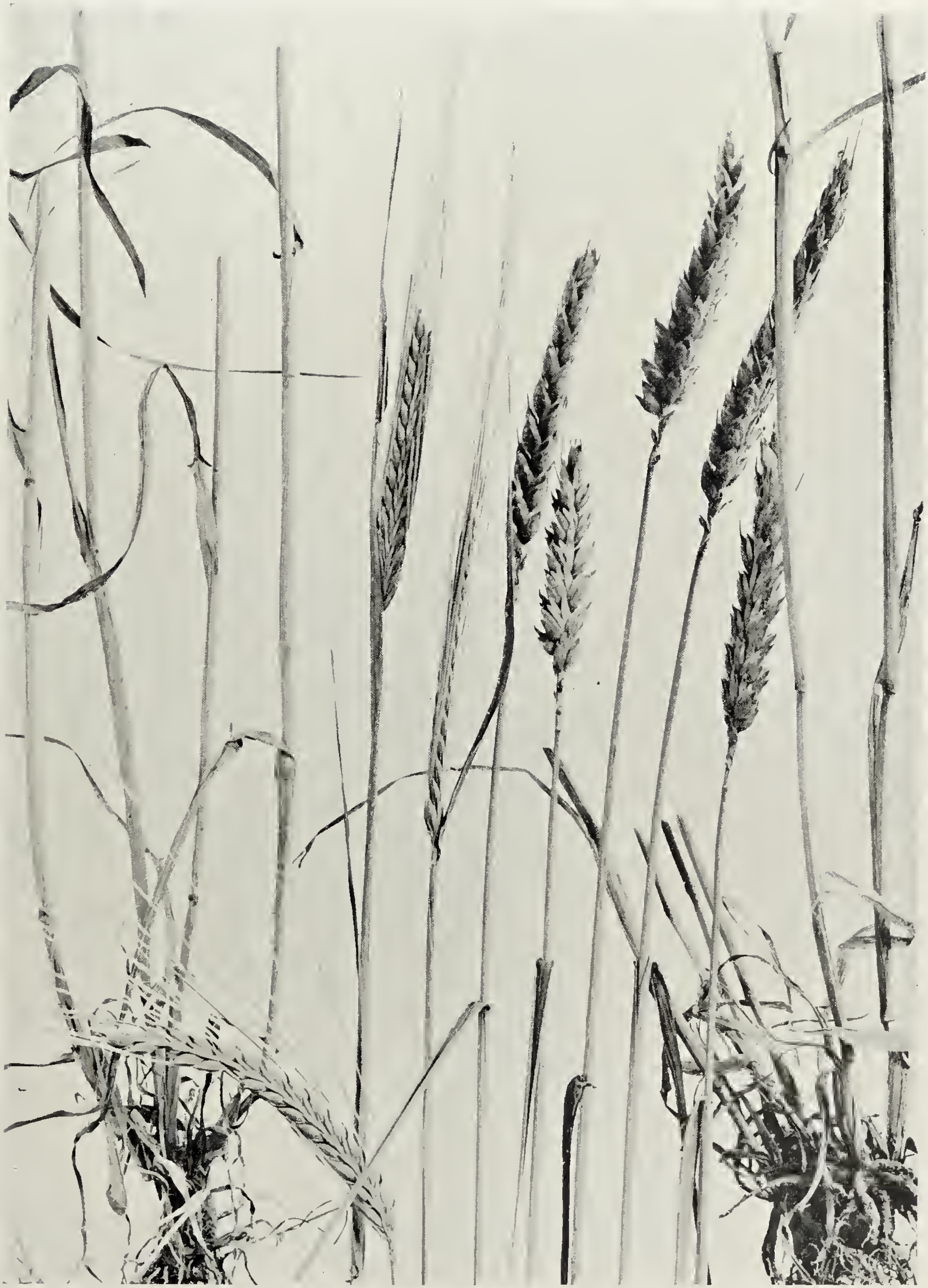


Photo by Henry Irving.

WHEAT (*Triticum vulgare*).

Showing the ears of wheat in various stages of ripeness.

PLATE XXI.

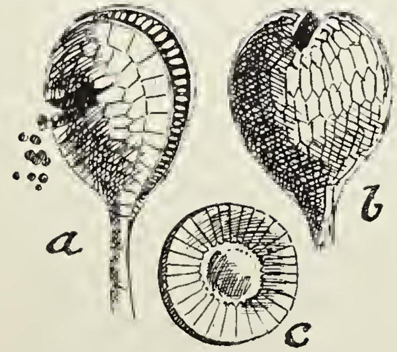


Fig. 125.—Sporangia of Ferns. (*a*) Of Maidenhair Fern (*Adiantum capillus Veneris*), with spores escaping. (*b*) Of flowering fern (*Osmunda regalis*). (*c*) Of rooting Bristle Fern (*Trichomanes radicans*).

attract the bodies on its surface, or the sun attract the earth? Still we are at a loss. We are familiar with facts, and are able to deduce what are called physical laws from them, but of the ultimate causes of the phenomena themselves we know nothing.

On removing a germinating grain of Barley from the ground, the young stem will be found to be surrounded at its base by a sheath (fig. 128), which is called the seed-leaf or *cotyledon*, and which should be particularly noticed. We shall refer to it again in a moment. The grain contains starch and gluten, and remains for some days adhering to the base of the young plant—a reservoir of nutriment. As growth proceeds this food supply diminishes, being conveyed to the seedling and used by it for evolving new protoplasm and cell-walls; nor is germination, properly speaking, at an end till the whole is used up, and the empty husk loosens from the plant. The proportions of starch and gluten (gluten, it should be remembered, is one of the proteids) vary in the different kinds of *Gramineæ*, or plants of the Grass order (Wheat, Rice, Maize, Millet, etc.), and on these relative proportions depend the alimentary properties of the various cereals.

Similar in some respects to the germination of Barley, though strikingly dissimilar in others, is the germination of a bean (figs. 129-135). In this case a primary root, formed by the direct growth and elongation of the embryo root or *radicle*, strikes down into the earth, and gives off lateral branches or secondary roots, which in their turn may send out a third series of branches, and so on (fig. 135). Meanwhile, the *plumule* or young stem, with its bent, yellow-green tuft, elevates itself above the soil, and straightens as it rises; while the tuft itself, expanding under the influence of solar light and heat, is seen to consist of two perfectly formed leaves—the first foliage leaves of the plant. Until these leaves are able to take in food from the atmosphere and to elaborate starch, etc., for themselves, the plant is dependent upon the

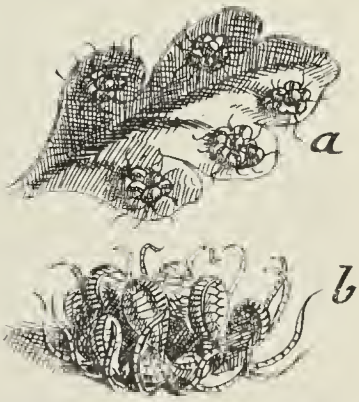


Fig. 126.—Sori of Round-leaved Woodsia (*Woodsia hyperborea*). (*a*) Part of a frond with five clusters of sori. (*b*) A single sorus of same consisting of a cluster of sporangia.

supply contained in its two seed-lobes or cotyledons, which, unlike the single cotyledon of a Barley grain, form the chief substance of the seed.

The young plants of Mustard (*Brassica alba*), Cress (*Lepidium*), Poppy (*Papaver*), etc., which are not thus liberally endowed, are thrown upon their own resources at a very early age, and have to work for their living almost directly they have broken from their shells. In such cases the cotyledons rise above the ground very soon after germination has commenced, and at once perform the functions of true leaves—developing chlorophyll and taking in carbon dioxide in a business-like and energetic manner. In this way the plants are kept alive and vigorous till ordinary leaves are produced (fig. 139).

By soaking a bean in warm water for a short time, the thick double skin or *testa*, with which it is surrounded, may be easily removed, and the two large fleshy lobes, which are the cotyledons of the embryo, may then be separated without difficulty, and the plumule and radicle laid bare (figs. 129-132). Before stripping the seed, the small black scar or *hilum* should be noticed; as well as a minute aperture at one end of it, the *micropyle*, from which a small quantity of water may be expressed if the moist seed be squeezed between the finger and thumb. When the testa has been removed and the cotyledons thrown open, the root of the germ-plant will be seen to be directed towards this aperture (figs. 133, 134).

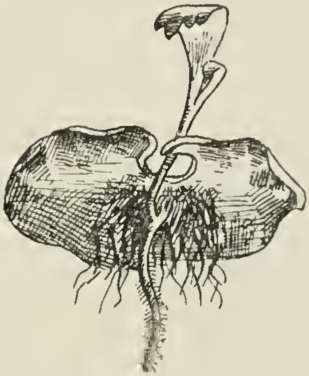
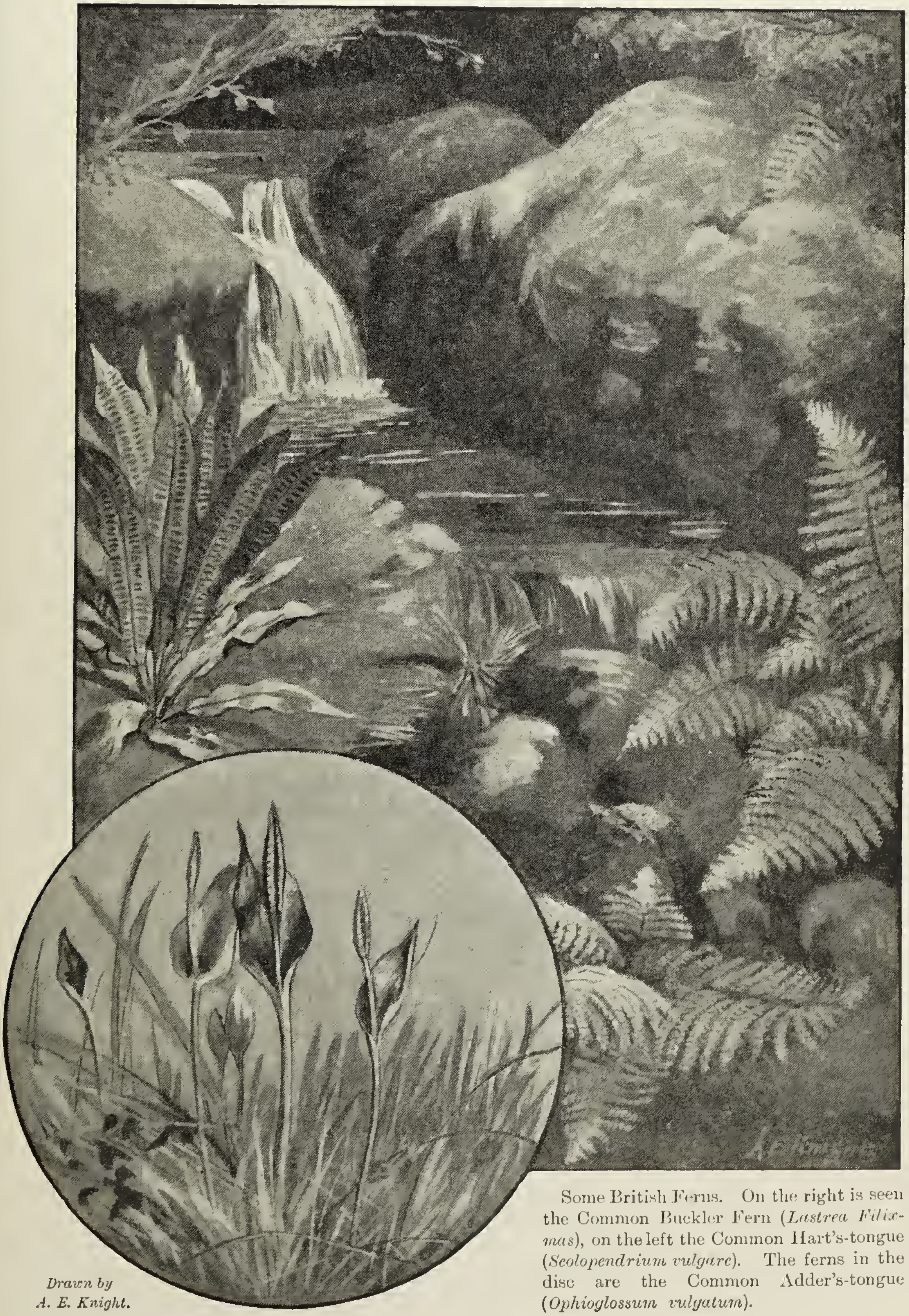


Fig. 127.—Prothallus of a species of Maidenhair Fern seen from below.

On stripping a seed of Maize (*Zea Mays*), a little examination will show how small a portion of the seed the single cotyledon occupies. Indeed, when the whole of the embryo plant, consisting of plumules, radicle, and cotyledon, has been picked out of the white floury matter in which it is embedded, it will be found that the bulk of the seed remains (figs. 140-143).

Thus in the one case the embryo forms the entire kernel of the seed; and in the other it is surrounded by a mass of albuminous tissue or *endosperm*, and occupies but a small part of the kernel. On this account, seeds of the latter kind are called *albuminous*, while those which, like the bean, contain no surrounding nutrient matter, are said to be *exalbuminous*. The terms are somewhat misleading, however, as the substance contained in the seed is not identical in chemical composition with animal albumen. It has characteristic differences in various plants. Thus it is mealy or farinaceous in cereals; fleshy in the Barberry (*Berberis*) and Heartsease (*Viola*); oily in the Poppy (*Papaver*) and Coconut (*Cocos nucifera*);



Drawn by
A. E. Knight.

Some British Ferns. On the right is seen the Common Buckler Fern (*Lastrea Filix-mas*), on the left the Common Hart's-tongue (*Scolopendrium vulgare*). The ferns in the disc are the Common Adder's-tongue (*Ophioglossum vulgatum*).

mucilaginous in the Mallow (*Malva*); cartilaginous in the berry of the Coffee-plant (*Coffea*); and hard and white like ivory in the Negro's Head Palm (*Phytelephas macrocarpa*). The endosperm of this palm forms the "vegetable ivory" of commerce.

In some seeds a part of the albuminous substance owes its origin to layers of cells outside and different from those which produce the endosperm, and hence it is given the distinguishing name of *perisperm*. In seeds of the Water-lily family (*Nymphæaceæ*), for example, the embryo plant is embedded in endosperm, which occupies the narrow end of the seed, while the rest of the albumen consists of perisperm. Ripe seeds of the Cannas (*Cannaceæ*), again, have no endosperm at all, the whole of the nutrient substance being perisperm.

For important reasons of classification the number and position of the cotyledons of seeds should always be carefully noted. We have seen that the spores of Fungi, Mosses, Ferns, and other cryptogamic plants never have cotyledons—they are not true seeds. We have also seen that grains of Barley and Maize, though possessing those organs, provide but *one* with each embryo; while both the bean and mustard seed have *two*. Therefore, looked at with reference to the germinating body, the plants above enumerated are of three kinds: those entirely destitute of cotyledons, or *Acotyledons*; those with only one cotyledon, or *Monocotyledons*; and those with two cotyledons, or *Dicotyledons*. The importance of this classification will be apparent when it is added that by far the greater number of known plants fall under one or another of these three divisions. Seaweeds, Fungi, Liverworts, Mosses, Ferns, and all other cryptogamic plants belong to the first division—they are Acotyledons; plants of the Grass, Rush, Sedge, Palm, Lily, Orchis, and Arum orders—in fact, the greater number of plants with parallel-veined leaves—are Monocotyledons; while most plants with net-veined leaves, whose name is legion, are Dicotyledons. The two great classes of Flowering Plants (Monocotyledons and Dicotyledons) have other characteristic differences, many of which will be found referred to in succeeding chapters. Thus the parts of the flower of a Monocotyledon are usually arranged in threes or sixes

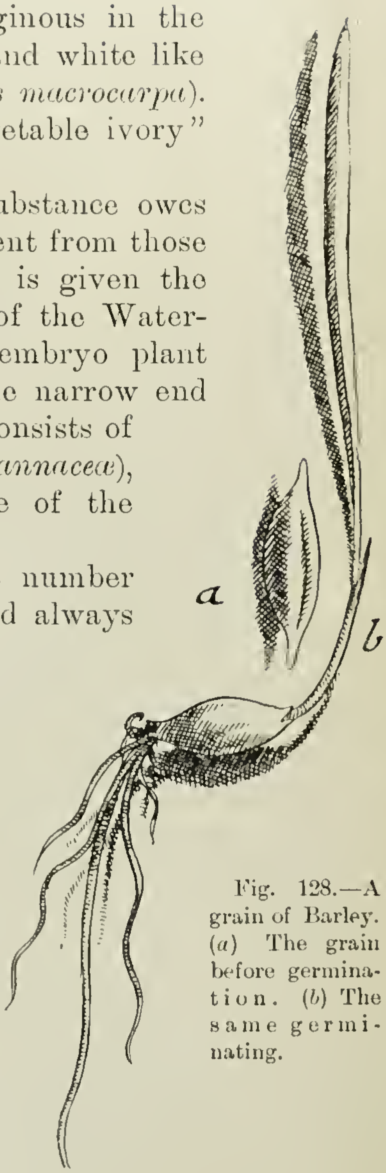


Fig. 128.—A grain of Barley. (*a*) The grain before germination. (*b*) The same germinating.

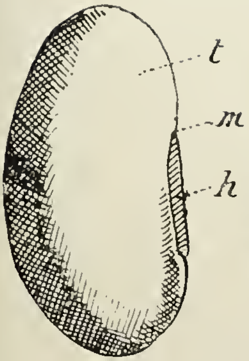


Fig. 129.—Haricot or French Bean. (*t*) Testa. (*m*) Micropyle. (*h*) Hilum.

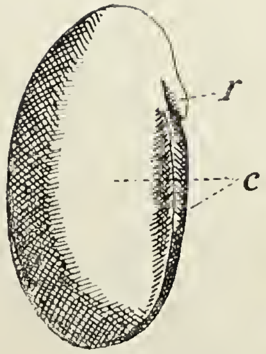


Fig. 130.—The same after removal of the testa, showing the two cotyledons (*c*) and the radicle (*r*).

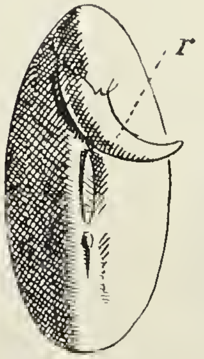


Fig. 131.—A Haricot Bean on the second day of the planting. (*r*) Radicle.

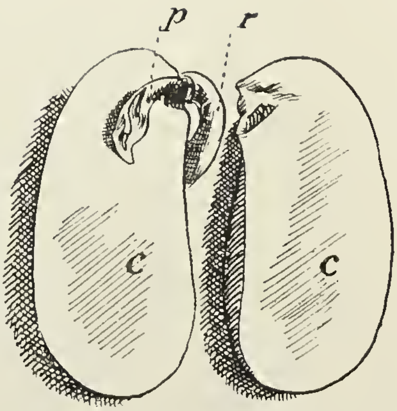


Fig. 132.—The same with the cotyledons (*c c*) laid open to show the plumule (*p*). The radicle (*r*) is partly hidden behind the left-hand cotyledon.

—three petals, three sepals, three stamens, and so on; while the floral organs of a Dicotyledon are generally arranged in fours or fives. The structure of the stem in each is also essentially different.

The seeds of a small number of Flowering Plants—chiefly parasites, as the Dodder (*Cuscuta*)—have no cotyledons; but these must be regarded as instances of vegetable degeneration, and such plants are classed among Phanerogams for other and sufficient reasons. Young plants of the Fir and Pine order (*Coniferæ*) sometimes have as many as twelve or even fifteen seed-leaves (figs. 145, 146), and thus form a small class by themselves, to which the name *Polycotyledons* has been given, though the term would hardly be accepted by present-day systematists.

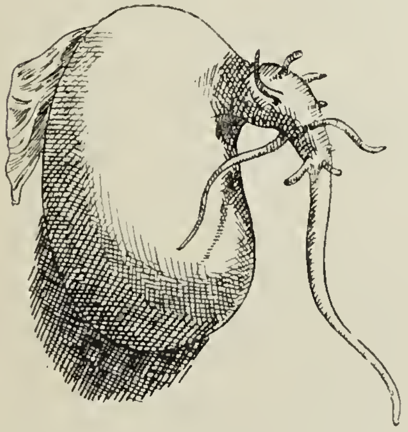


Fig. 133.—A Haricot Bean on the fifth day after planting, showing the plumule breaking its way through between the cotyledons.

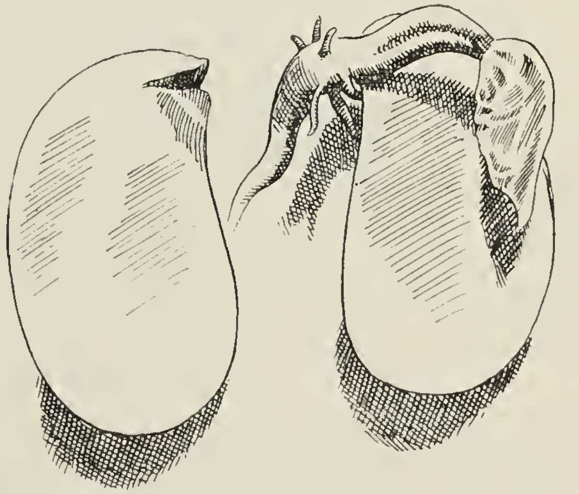


Fig. 134.—The same with the cotyledons laid open.

Instances have been recorded of Dicotyledons with *three* cotyledons (!), but such cases are abnormal, and should be classed among freaks of nature. Seedling Maples have manifested this peculiarity, and a specimen of a tricotyledonous Oak may be seen in one of the museums of economic botany at Kew (fig. 147).

Many curious facts have been discovered by Darwin with reference to the movements of plants, and not the least curious are those which relate to the movements of the cotyledons and roots of seedlings. Of the young plants which he examined, the cotyledons in some cases kept up a continuous movement in a vertical direction; in others they oscillated from side to side, the seed-leaves always acting together—save, indeed, in a solitary instance, where one cotyledon rose while the other fell, the plant which exhibited this exceptional movement being a species of Wood-sorrel.

The young growing rootlets likewise exhibited a constant slow movement from side to side,* their tips, which displayed the most exquisite sensitiveness, enabling them to avoid destruction and threatened injury, and to feel their way downwards between the particles of the soil. "A radicle," says Darwin in his *Movements of Plants*, "may be compared with a burrowing animal, such as a mole, which wishes to penetrate perpendicularly down into the ground. By continually moving his head from side to side, or circumnutating, he will feel any stone or other obstacle, as well as any difference in the hardness of the soil, and he will turn from that side; if the earth is damper on one than on the other side, he will turn

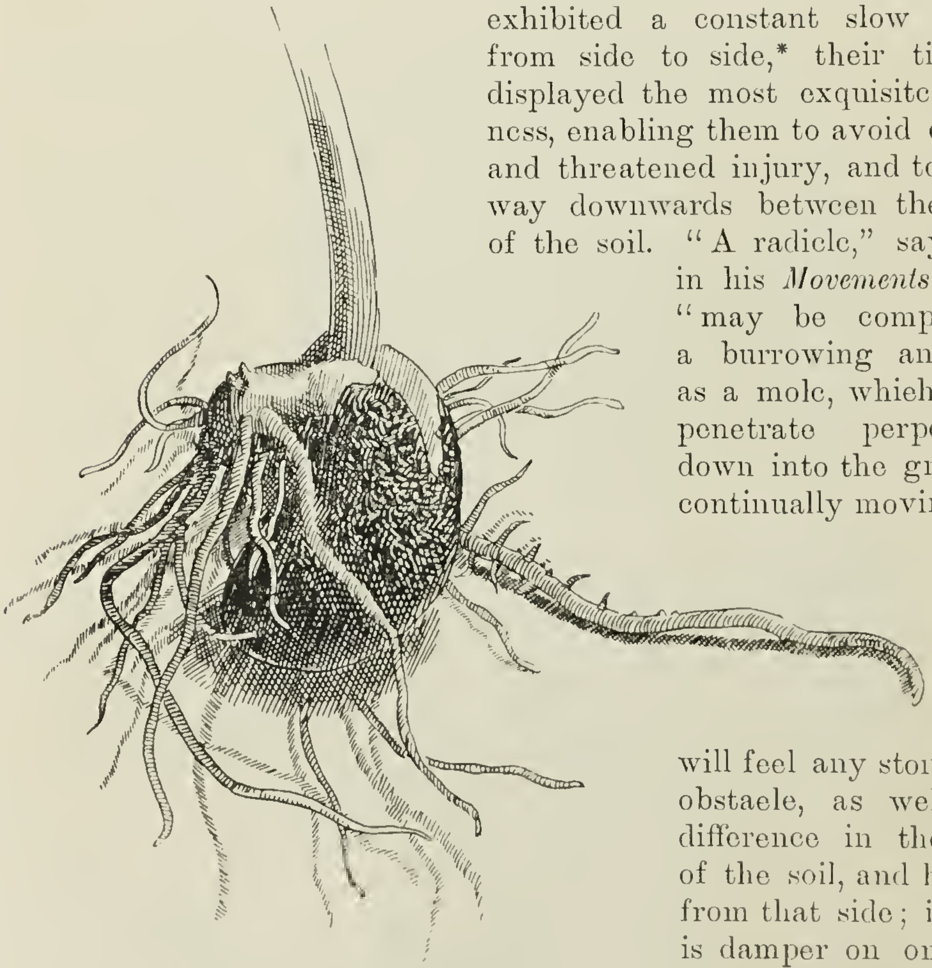


Fig. 135.—A Haricot Bean at a still later stage.

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* The path is really a spiral—a circumnutation.

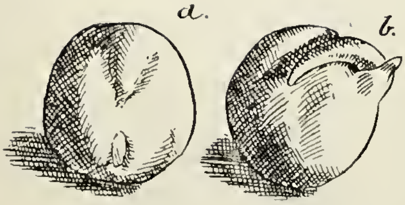

Fig. 136.—A Pea. (*a*) First day: the testa beginning to swell the growing radicle. (*b*) Second day: the radicle breaking through.

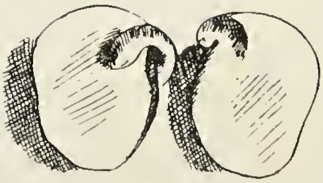

Fig. 137.—The same: the cotyledons laid open to show the plumule.

thitherwards as a better hunting ground. Nevertheless, after each interruption, guided by the sense of gravity, he will be able to recover his downward course, and to burrow to a greater depth."

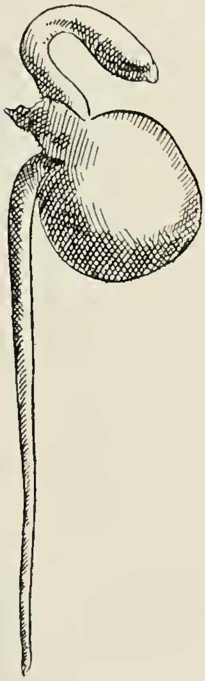

Fig. 138.—A germinating Pea on the fourth day.

Note, too, how the sensitiveness of the root and rootlets struck Mr. James Rodway during his study of plant life in the forests of Guiana: "Roots are undoubtedly able to distinguish suitable from unsuitable food, and though they may be poisoned now and then, this is nothing strange, as the same thing happens to man. Their sensitive tips go wandering in every direction, branching here and there in search of proper food. As long as the soil is uncongenial they press forward, and only when a good feast is discovered do they throw out that broom-like mass of fibres so conspicuous on the banks of rivers and creeks. A barren subsoil is carefully avoided by keeping to the surface, while in the rich river bottom the sour, water-logged alluvion is equally distasteful. On the sand-reef the tap-roots go down fifty feet or more, and spread most evenly to glean every particle of food contained in the water that has percolated to these depths. On the mountain, again, every chink and cranny between the rocks is explored, the roots sometimes penetrating through narrow crevices into hollows where water has accumulated,

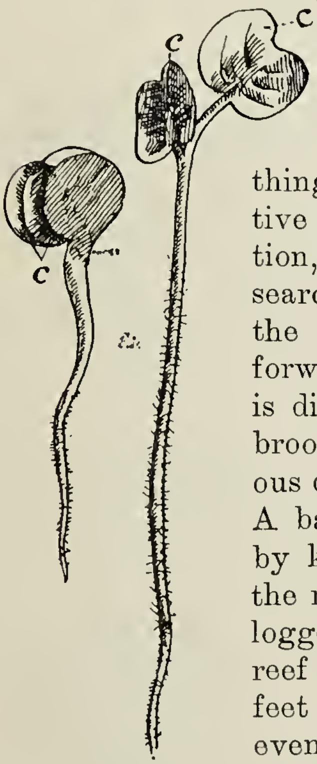

Fig. 139.—Germinating Mustard seeds at a very early and at a slightly later stage. (*c*) Cotyledons which are pushed above the soil by the upward growing stem, and perform the function of true leaves.

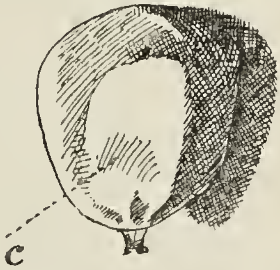

Fig. 140.—A fruit of the Maize-plant (*Zea Mays*). (*c*) The cotyledon.

and spreading their network of fibres over the roof, down the walls, and into the pools. In some cases it appears as if the roots smell the water at a distance, and move straight onwards until they reach it. Some epiphytes that push their aerial roots down the trunks of trees in the forest hang them quite free when above the water, only allowing them to branch out when they reach the surface. In the first case moisture is obtained from the rain and the dew as they trickle down the little channels in the bark, while in the other a reservoir of water is below, and the plant seems to know it."

An extremely curious instance of the motility of young roots is furnished by an Indian species of *Loranthus*, nearly related to the Mistletoe (*Viscum album*), and,

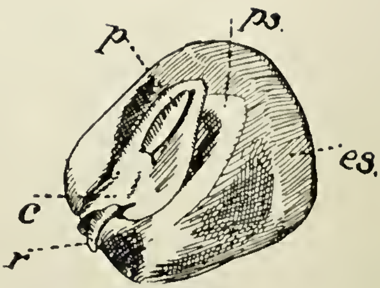

Fig. 141.—The same, the testa having been removed to show the embryo, consisting of plumule (*p*); radicle (*r*); and cotyledon (*c*) embedded in white mealy perisperm (*ps*), the outer layers of which (*es*) are yellow. [*Note.*—The embryo has been partly lifted out from the perisperm in order to show the several parts more clearly.]

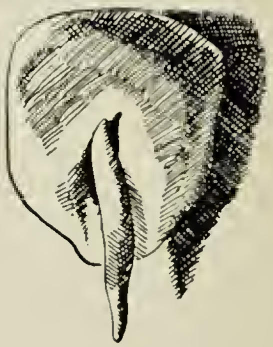

Fig. 142.—A fruit of Maize on the fourth day of germination. The testa has been removed.

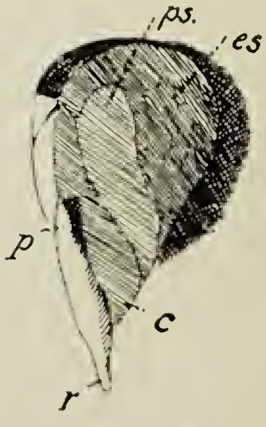

Fig. 143.—The same in vertical section.

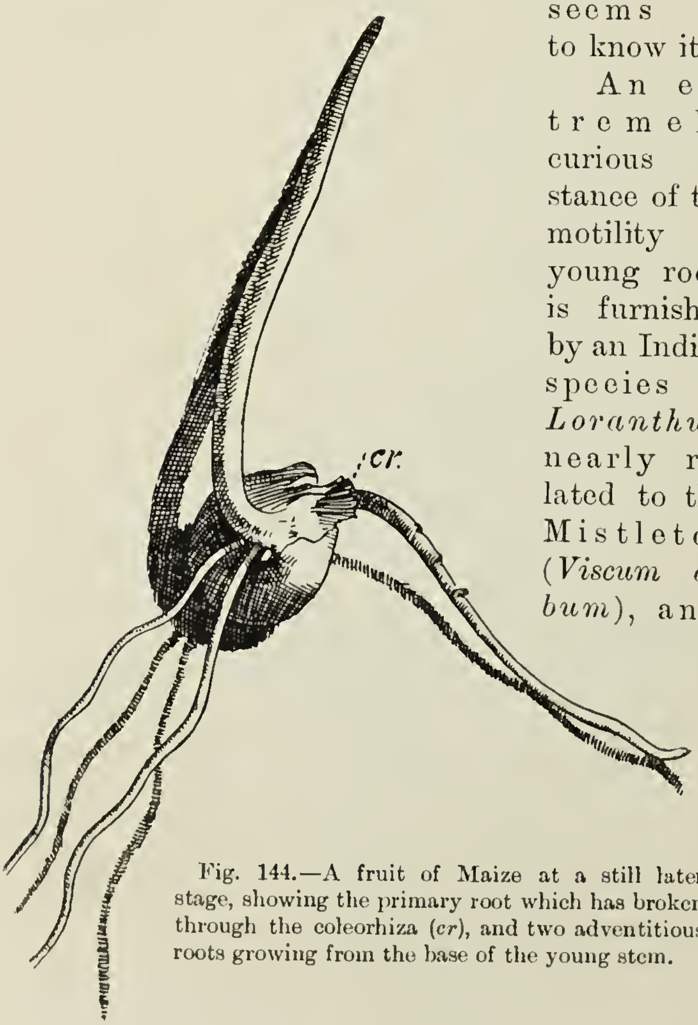

Fig. 144.—A fruit of Maize at a still later stage, showing the primary root which has broken through the coleorhiza (*cr*), and two adventitious roots growing from the base of the young stem.

like it, a parasite on trees. The fruit contains bird-lime — a peculiar viscous, tenacious, and elastic substance—and when the berry loosens from the plant, it sticks to whatever it falls upon. The seed is embedded in the viscid pulp, and germination commences in the following manner: "The radicle," says Mr. N. E. Brown, "at first grows out, and when it has grown to about an inch in length, it develops upon its extremity a flattened disc; the radicle then curves about until the disc is applied to any object that is near at hand. If the spot upon which the disc has fastened is suitable, the germination continues, and no locomotion takes place; but if the spot should not be a favourable one, the germinating embryo has the power of changing its position. This is accomplished by the adhesive radicle raising the seed and advancing it to another spot, or, to make the process plainer, the disc at the end of the radicle adheres very tightly to whatever it is applied to; the radicle itself straightens, and tears away the viscid berry from whatever it has adhered to, and raises it in the air. The radicle then again curves, and the berry is carried by it to another spot, where it adheres again. The disc then releases itself, and by the curving about of the radicle is advanced to another spot, where it again fixes itself. This, Dr. Watt says, has been repeated several times, so that to a certain extent the young embryo, still within the seed, moves about. It seems to select certain places in preference to others, particularly leaves. The berries on falling are almost certain to alight upon leaves, and although many germinate there, they have been observed to move from the leaves to the stem, and finally fasten there" (*Gardener's Chronicle*, 1881).

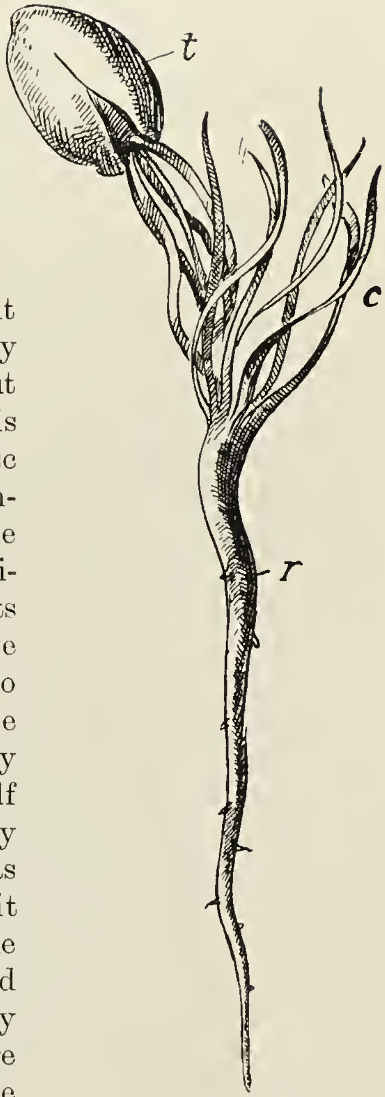

Fig. 145.—Germination of the seed of a Pine (*Pinus*). (*t*) Testa of seed. (*c*) Cotyledons. (*r*) Primary root.

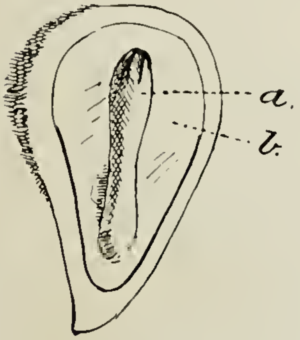

Fig. 146.—Seed of the Common Larch (*Larix europea*) in vertical section, showing the polycotyledonous embryo embedded in endosperm.

Though the direction of the roots is normally downwards, it would appear from experiments begun by Colonel Greenwood more than fifty years ago that they will grow in any direction in which they can find food The colonel placed a number of Horse-chestnut seeds in flower-pots, which he suspended in an inverted position on wirework, and watered the seeds from above. The main-root which each seed sent down into the air presently died; but the branch-roots, *which had not taken a downward course*, continued to grow, and the plants flourished. He had thus stumbled upon the fact that the seedlings of the Horse-chestnut have a primary root whose downward determination nothing can pervert, "a provision and contrivance for the fixing of the plant, and a beautiful proof of the design of a Creator"; but that this downward root is as peculiar to the seedling as the seed-leaves are, and, moreover that the branch-roots will grow in any direction. The experiment did not end here. For upwards of twenty years Colonel Greenwood preserved one of the plants in its inverted position,* by placing it on a flat stone and exchanging the flower-pot, when the branch-root grew too long for it, for a chimney-pot full of earth; and so adding another and another, as occasion required, till the column was seven feet high. Then he turned the root over a wall into a similar column of earth on the other side, thus permitting it to take, for the first time, a downward direction. When at last this much-abused organ reached the ground, the colonel removed both of the artificial columns; and the plant, with a naked, arching root, fourteen feet in length, was left to its own resources (*Athenæum*, 1864).

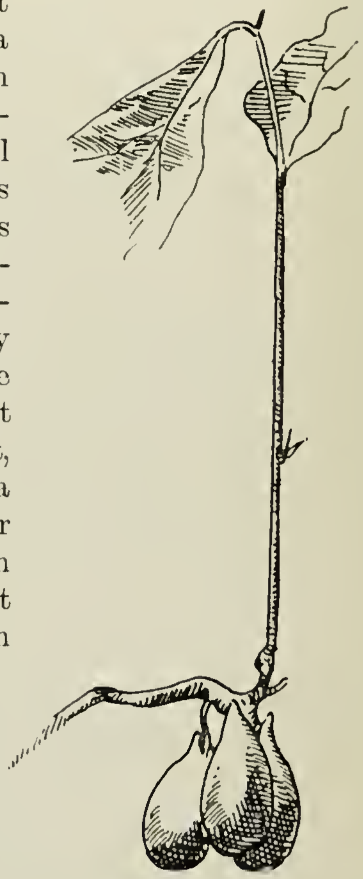

Fig. 147.—Germinating acorn with three cotyledons; drawn from the specimen preserved in the museum for economic botany, Kew Gardens.

Seeing that roots are such wonderful—we had almost said versatile—organs, it may be interesting to look a little at their structures. The root-section shown (fig. 148) is that of a young Maple (*Acer campestre*). Notice particularly the layers of rather long cells (*a*) at the extremity of the root. These constitute the *root-cap*,† and form a sort of protecting shield to the dense cluster of smaller cells hidden immediately within the end of the sheath, which form the growing-point of the root. All the wear and tear to which these delicate-growing cells would be subject is borne by the sturdier root-cap: while the growing-point makes some compensation for the services thus rendered by fabricating new cells for the sheath on its inner side, as its outlying cells become worn and withered in the rough pioneer work which they perform. In the centre of the root is a bundle containing woody vessels—the *vascular cylinder* or *stele*—which constitutes, in conjunction with the rest of the vascular system, the mechanism by means of which the crude sap is carried upwards to the leaves, there to be elaborated into nutrient material. In nearly every species of plant there is but one of these steles in each root, but in a few—chiefly palms—the roots are *polystelic.* The tissue of rather thickened cells (*endoderm*) surrounding the stele is parenchyma (*pm*), which forms a strong padding and hermetically closes the central cylinder, thus preventing passage of air while allowing that of water. It is known as the *root-sheath.* In most plants with biennial and perennial roots the root-sheath serves the further purpose of a repository for food material—starch, fat, sugar, or whatever other supplies may be needed for the next period of vegetation. Surrounding the tissue is a mass of cells (the cortex) consisting of thinner-walled parenchyma, in which also reserve materials are deposited; and then, last of all, we have the epidermis (*e*), with its unicellular root-hairs (*f*), those delicate organs by which the plant dissolves—and through which are absorbed—the inorganic substances which constitute, with water, the crude ascending sap.

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* Inverted as regards the root.

† The *pileorhiza* of some botanists.

As a protection against field-mice, insect larvæ, and other underground animals, many food-storing roots develop poisonous and disagreeable substances in their tissues, in the way of noxious alkaloids, fœtid gum resins, and other products well known to druggists; and it has been observed that such roots are very seldom attacked. "The field-mice in a garden at Innsbruck," says Kerner, "once caused great havoc under the winter coat of snow, and various roots were gnawed by them; but the roots and root-stock of the Soapwort (*Saponaria officinalis*), containing quantities of poisonous saponin, were always left untouched by them." A similar fact was observed elsewhere of several species of Gentian (*Gentiana punctata*, *lutea*, and *pannonica*), as well as of the thick and poisonous main-roots of Monkshood (*Aconitum Napellus*), the massive roots of the Rhubarb-plant (*Rheum officinale*), and many *Umbelliferæ.*

The fact that the root is often a storehouse of nutritious food substances has an important morphological bearing, almost all departures from a slender tapering form—at least in the young root—being chiefly due to it. The carrot and turnip, for example, are simply the primary roots of *Daucus Carota* and *Brassica Rapa* swollen up with reserve material (figs. 150–152; see p. 106). These primary or main roots are known as *tap-roots*; though various qualifying names—such as *conical*, *fusiform* or spindle-shaped, and *napiform* or turnip-shaped—are given, according to the special form which the tap-root assumes. Occasionally the tap-root divides into two or three forks, as in the poisonous Mandrake (*Mandragora officinalis*), where they have a fancied resemblance to the human form (fig. 153)—though this is not the origin of the name of the plant. In days of popular ignorance and credulity the Mandrake was looked upon with superstitious awe by all classes, and its roots were said to be endowed with animal feelings, and to shriek when torn from the earth! It was, therefore, accounted dangerous to disturb them.

Fibrous roots are seen in the Grasses, Buttercup (*Ranunculus*, fig. 154), etc., the name being given to branch-roots which are very slender. The fibres sometimes penetrate to a greater depth than people are inclined to suppose, particularly when the subsoil is hard and dry, and the plants are needing more abundant nourishment. Even in rich garden soil the roots of Wheat (*Triticum*) have been traced to a perpendicular depth of five or six feet. This, however, is nothing in comparison with the depth to which some tap-roots will penetrate. One hundred and ten feet is the computed length of the tap-root of a Baobab-tree (*Adansonia digitata*) in Adanson's account of Senegal; but this, we need scarcely add, is exceptional.

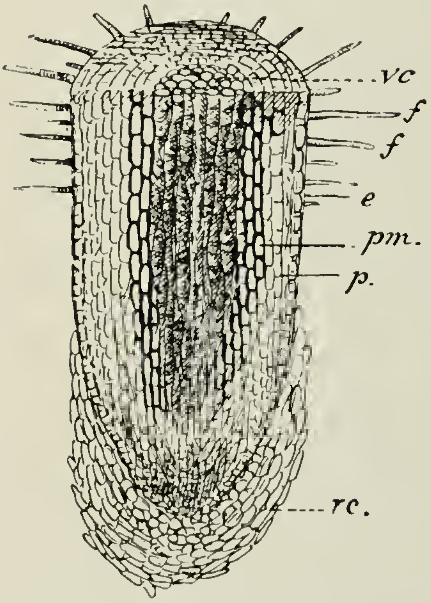


Fig. 148. — Root-section of young Maple. (Lettering explained in the text.)

In the fibrous roots of many plants we find peculiar swellings and thickenings, which serve (like the different forms of tap-root) as reservoirs of nutritious matter; and these may all be described as *tuberous roots* (fig. 155). *Care must be taken, however, not to confound a tuberous root with a tuber*, which last is not a root at all, but a fleshy underground stem (cf. Chapter VII.). In *Pelargonium triste* the tubercles or swellings give the fibres a beaded appearance, and hence the root is described as *moniliform* or necklace-shaped (fig. 156); while in the Common Dropwort (*Spiræa Filipendula*) the fibres bear irregularly shaped knobs or nodules towards the ends; and this kind of root is distinguished as *nodulose* (fig. 157). Both forms are fairly common. A far less frequent form is the *annulated* (fig. 158), in which the fibre-expansions have a ring-

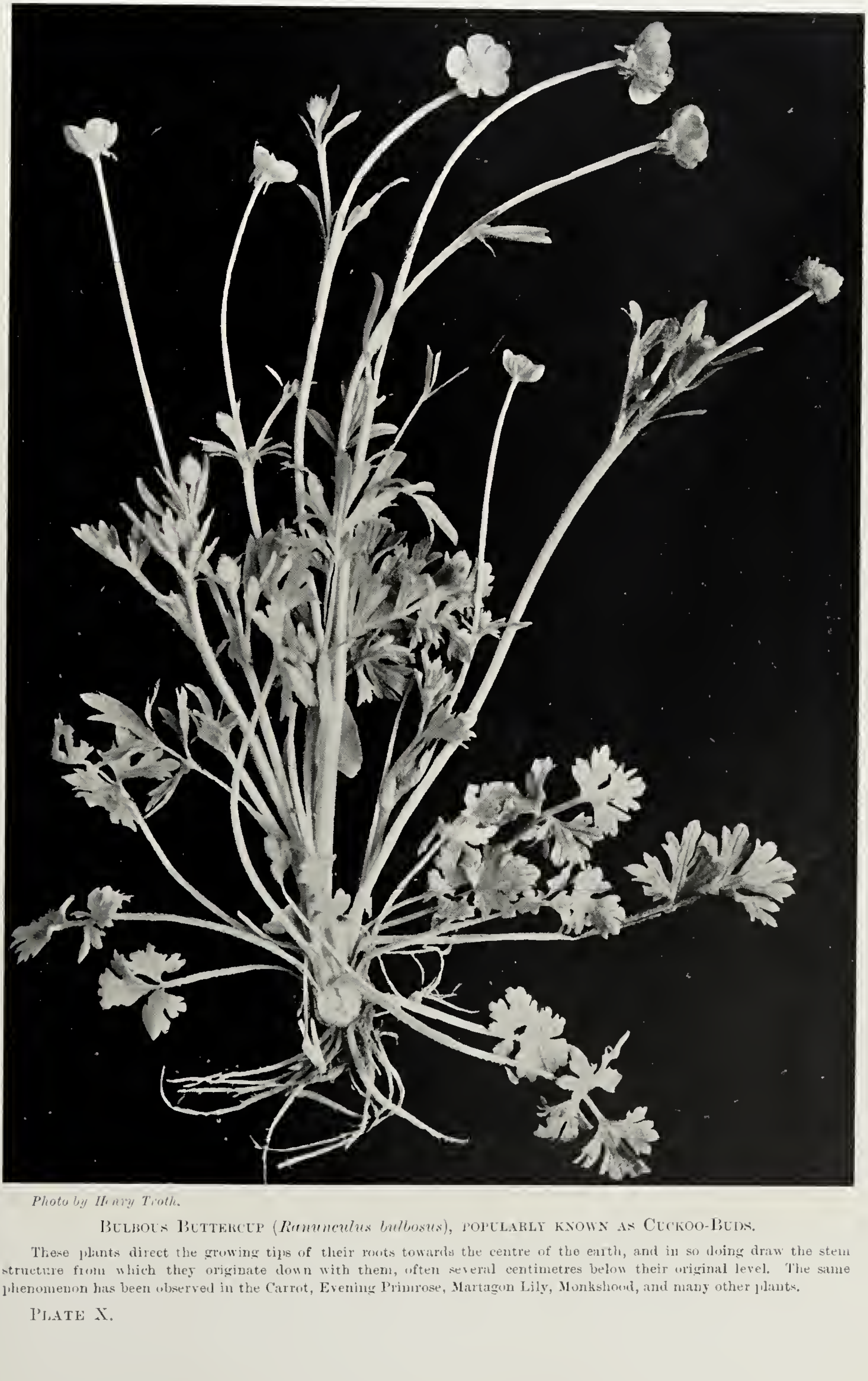


Photo by Henry Troth.

BULBOUS BUTTERCUP (*Ranunculus bulbosus*), POPULARLY KNOWN AS CUCKOO-BUDS.

These plants direct the growing tips of their roots towards the centre of the earth, and in so doing draw the stem structure from which they originate down with them, often several centimetres below their original level. The same phenomenon has been observed in the Carrot, Evening Primrose, Martagon Lily, Monkshood, and many other plants.

PLATE X.

like appearance. Of this we have an excellent example in the well-known Brazilian plant, *Cephaëlis Ipecacuanha*, which yields the valuable drug of that name. Ipecacuanha formed the basis of the medicine with which the Dutch physician, Adrien Helvetius, treated dysentery so successfully in the seventeenth century; and he had cause to bless the root. The fame of the celebrated medicine spread to the Court of France, and Louis XIV. gave the fortunate doctor a thousand louis d'ors to reveal the secret of its composition.

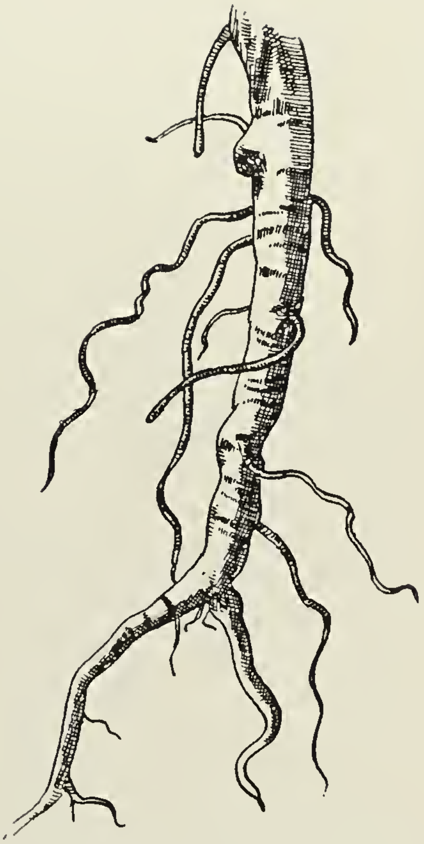


Fig. 149.—Tap-root of Common Liquorice (*Glycyorhiza glabra*).

Testicular and *fascicular* roots have also been looked upon as varieties of the fibrous form by some writers; though others—certainly with less reason—have regarded them as variations of the divided form of tap-root. Perhaps it would be more fitting to place them in a group by themselves, for they seem rather to form a link between those classes than to belong exclusively to either. The peculiarity of the testicular root (fig. 160) is that some—usually two—of its divisions become fleshy and enlarged so as to form more or less egg-shaped expansions; while in the fascicular root the clustered rootlets become swollen along their length, and look like a bundle of spindle-shaped (fusiform) roots (fig. 159).

We might tabulate the chief forms of subterraneous roots in the following manner:—

TAP-ROOTS.
- 1. Conical.
- 2. Fusiform.
- 3. Napiform.

FIBROUS ROOTS.
- 1. Non-tuberous.
- 2. Tuberous—
  - *a.* Moniliform.
  - *b.* Nodulose.
  - *c.* Annulated.

QUASI-FIBROUS ROOTS.
- 1. Tuberous Fascicular.
- 2. Tuberous Testicular.

Certain plants with spreading fibrous roots subserve a useful purpose by binding together the loose sand on the seashore, and raising those banks which, as in Norfolk, defend the country from the encroachments of the sea. Of this sort are the Lyme-grass (*Elymus arenarius*), the Sea-sedge (*Carex arenaria*), the Marram (*Psamma arenaria*), and the beautiful *Eryngium maritimum*, or Sea-holly, so well described by Dr. Drummond:—

> The *Eryngo* here
> Sits as a queen among the scanty tribes
> Of vegetable race. Around her neck
> A gorgeous ruff of leaves, with arrowy points,
> Avert all harsh intrusion. On her brow
> She binds a crown of amethystine hue,
> Bristling with spicula, thick interwove
> With clustering florets, whose light anthers dance
> In the fresh breeze, like tiny topaz gems.
> Here the sweet Rose would die. But she imbibes
> From arid sands and salt sea dewdrops, strength;
> The native of the beach, by Nature formed
> To dwell among the ruder elements.

The Marram, mentioned above, was the subject of an Act of Parliament in Queen Elizabeth's time, the purpose of the Act being to encourage the cultivation of this grass and prevent its destruction. Its preservation is still carefully provided for by the "bank-reeves."

The dunes on the shores of Holland and Denmark have been an object of care by the Government for an even longer period than have the English dunes; and there, also, resort is had to the cultivation of grasses and creeping plants, while burrowing and grazing animals are rigidly excluded. In certain parts of France and North America, again, similar means for resisting the encroachments of shifting sands have been extensively employed for many years; and the method has been greatly improved upon and developed.

So far back as 1780, M. Brémontier, an eminent French engineer, devised the means (first suggested, it is said, by a priest of Mimizon) of fixing the dunes. The practical value of his theories, which were adopted by the then Government, has been fully established by the experience of a century. An American savant, Mr. G. B. Emerson, bears this testimony: "I visited, in 1872, the region saved by Brémontier, and examined the work he had done, and its effects. The whole country, for more than a hundred miles along the

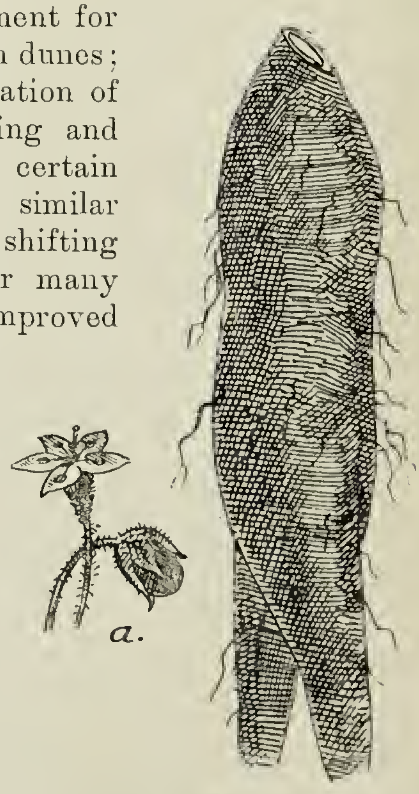


Fig. 153.—Mandrake root. (*a*) Flower and fruit.

Atlantic coast of Gascony and from four to eighteen landward, had been covered with sand-hills. . . . The process of ruin had been going on for centuries, and some of the sand-hills were hundreds of feet high. In the midst of this recovered region I stopped a day or two at a beautiful town, where a hundred thousand persons from Paris and other cities of France, attracted by the genial climate and the health-giving atmosphere of the pine forests, had passed the winter. I walked and drove along the sandy roads, visited a monument to Brémontier, erected by his brother, ten miles or more inland in the redeemed territory, and saw in many places deciduous trees—oaks, ashes, beeches, and others—growing luxuriously under the protection of the pines. One cannot help feeling while enjoying this the justice of our countryman Marsh, who counted Brémontier, and Reventloy, who conducted a similar work in Denmark, as amongst the greatest benefactors of their race."

Brémontier's method is briefly this : A continuous wooden paling about four feet high is erected parallel with the shore-line, and about a hundred yards back from high-water mark, a space an inch wide being left between the boards. As the sand is not raised like dust, but glides along near the surface, it piles up in front of the paling, and, passing through the crevices, is deposited behind. This goes on till the boards are buried, when they are raised one at a time, and the operation is continued. By repeating the process again and again the dune steadily rises in height and assumes a slope of from seven to twelve degrees in front, and much less on the land side. On setting the first fence, tufts of *Psamma arenaria* are planted in front, and in a belt eight times wider than the obstacle opposed. These tufts are in quincunx order, and closer together near the paling. Those outside stop some of the sand, those farther up stop more, and thus an even slope of the desired angle is secured and maintained. The tufts are set in winter, and between them are sown seeds of the same plant, and of *Triticum junceum*, *Artemisia*, *Kakile maritima*, *Salsola*, *Ephedra*, and other maritime plants. These

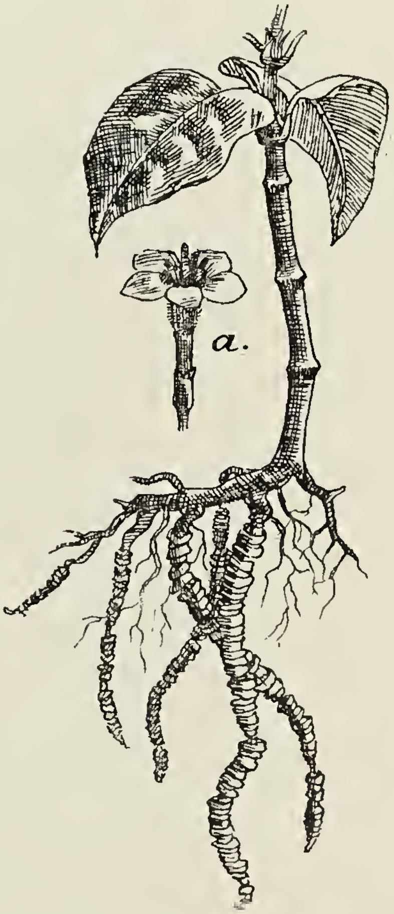


Fig. 158.—Annulated root of *Cephaëlis Ipecacuanha.* (*a*) Flower.

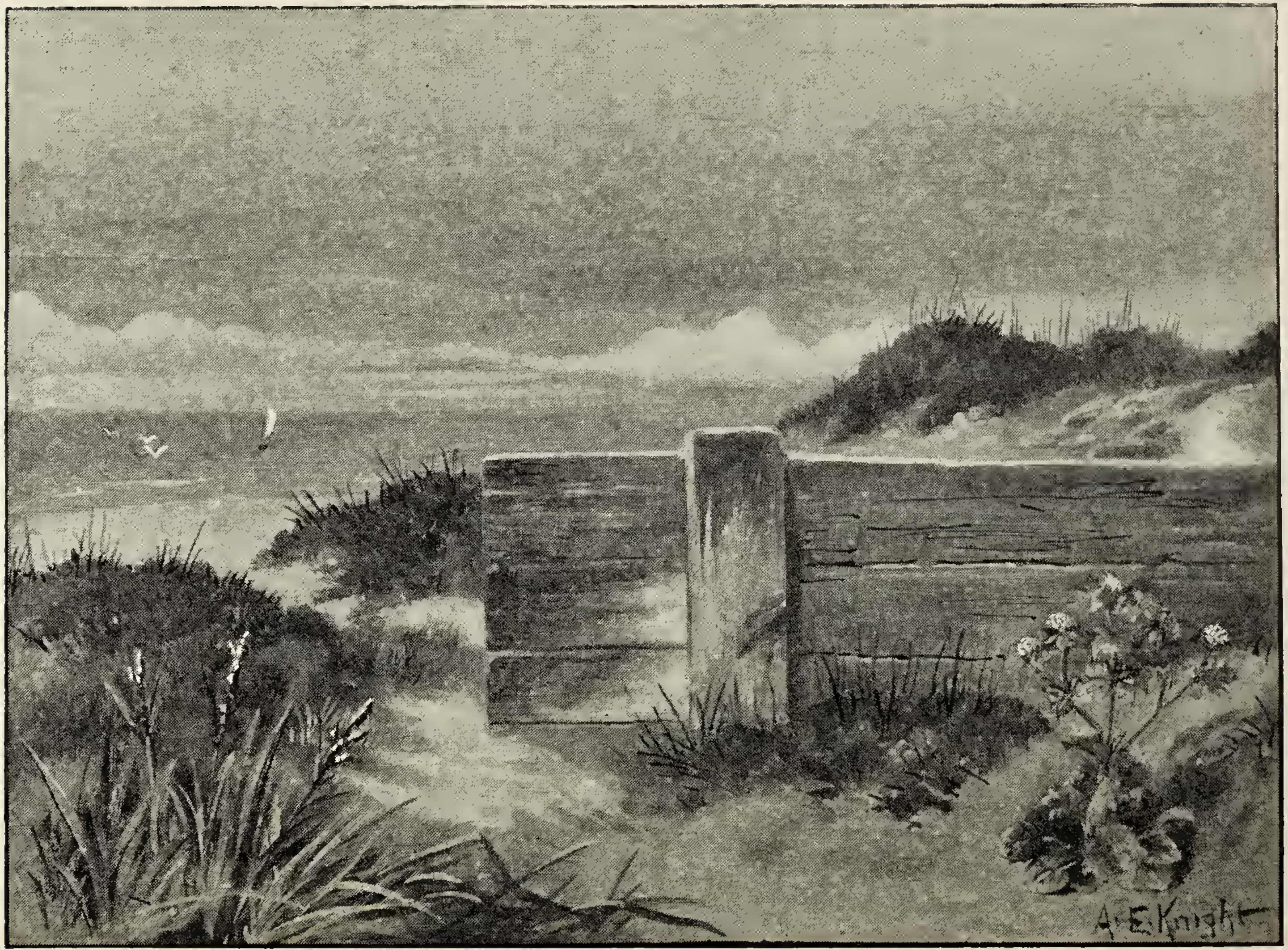
grasses, etc., grow upward as they are buried, and thus the sand is bound together in a fine network of fibres. Then, at a fit time, the surface is sown broadcast with a mixture of seeds of the Maritime Pine (*Pinus Pinaster*), the Common Broom (*Sarothamnus scoparius*), Furze (*Ulex nanus*) and Marram (*Psamma arenaria*). These sprout and come up together, the tender shoots of the pine growing well when screened by the other plants. Thus the land is saved.

The planting of the same grass on the dunes of Cape Cod, in the State of New York, has been practised since colonial days; and similar conservative measures were ordered by law upon the beaches of Long Island as early as 1758. On the Florida coast, the Bermuda-grass (*Cynodon Dactylon*) has been successfully used in fixing loose sands. Its roots creep to a great distance, with short flattish leaves, sending up flowering shoots a few inches high at intervals, which bear seed and spread. It runs over the sand in zig-zag form, with joints at each angle six or eight inches apart, from each of which a root strikes into the ground, soon forming a most effectual network of roots through the loosest sand.

Roots which issue from the stem, as distinguished from those which result from the development of the radicle, are spoken of as *adventitious*. We have seen that the roots of Barley are of this description, and it is noteworthy that the greater number of Monocotyledons exhibit the same kind of growth. The well-known Pandanus-trees or Screw-pines, of which there are many species, are remarkable for their adventitious roots, which continue to be given off by the stem long after it has appeared above the ground (p. 135). These aerial roots, which are furnished at their extremities with special cup-like root-caps in which to catch the rain and dew, grow downwards in the air till they reach the ground, when the cups fall off, and the denuded organs proceed to act in the ordinary manner of underground roots. The slender-stemmed plant, which is often top-heavy with its massive crown of leaves, derives welcome support from this very curious arrangement.

As incidental reference has just been made to *aerial roots*, perhaps this is the most fitting place to offer what little we have to say about those interesting organs.

Plants which grow within the inter-tropical regions show a very conspicuous tendency to develop roots above-ground; and the phenomenon is not confined to one family or order, but has been observed in plants very far removed from one another in the system of Nature. Moreover, the objects for which such roots are produced may vary greatly. Thus, some roots (like those of the Pandanus-trees just mentioned) answer the purpose of *supports*. The *Paxiuba* (*Iriartea*), a tall, erect, smooth-stemmed Palm with large crown of curiously cut leaves, found in the Amazon region,



Drawn by A . E. Knight.

Some Vegetable Coastguards.

is remarkable on this account. "Its great singularity," says Dr. Wallace, "is that the greater part of its roots are above-ground, and they successively die away, fresh ones springing out of the stem higher up, so that the whole tree is supported on three or four stout straight roots, sometimes so high that a person can stand between them with the lofty tree growing over his head. The main-roots often diverge again before they reach the ground, each into three or more smaller ones, not an inch each in diameter. Though the stem of the tree is quite smooth, the roots are thickly covered with large tuberculous prickles. Numbers of small trees of a few feet high grow all around, each standing on spreading legs, a miniature copy of its parent."

Then there are *feeding* aerial roots. A large number of tropical Orchids, epiphytic on old trees, besides possessing naked air-roots which subserve the purpose of attachment, have others which are modified for the absorption of nutriment from the surrounding atmosphere—indeed, in a few cases the Orchid has no green leaves (*e.g.*, *Polyrhiza*); the roots do everything. These modified roots hang down from the stem or branch of the tree to which the plant is anchored, in white thread-like bunches, the whiteness being due to a papery membrane which envelops the green chlorophyll-containing cells of the true roots. This covering is composed of perforated cells, and acts like a sponge. "When it comes in contact with water in the liquid state," says Kerner, "or more especially when it is moistened by atmospheric deposits, it imbibes instantaneously its fill of water. The deeper-laying living green cells of the root are thus surrounded by a fluid envelope and are able to obtain from it as much water as they require." Moreover, this porous tissue possesses the power of condensing aqueous vapours and other gases; so that a Tree-orchid is absolutely independent of its host for nourishment.

It will be evident from the above facts that the papery envelope has a twofold use. In the dry season it reinforces the safeguards provided by the root against too profuse transpiration on the part of the living green cells in the interior; "and in the wet season," as Kerner remarks, "it provides for the continuous supply of the requisite quantity of water." The air-roots of many Aroids and Tree-ferns answer much the same purpose; but this is not the case with the peg-like aerial roots of Ivy (*Hedera Helix*), which are simply intended for mechanical support. The nourishment required by the Ivy is obtained in an entirely honourable manner by its leaves and underground roots; and the rather rough treatment which the plant has received from some writers on account of its supposed parasitical tendencies is, to say the least, unfortunate. One poet charges it with having "hid the princely trunk, and sucked the verdure out on't"; but the prejudice on which the accusation is based has no foundation in fact. The plant has competent defending counsel in another poet, Calder Campbell, who enshrines its woes in the following graceful verse :—

> They blame me, they blame me
> Who understand me not ;
> They say I suck the green bough's blood
> Till all its leaflets rot.
> They say my roots beset the bark
> Until 'tis little worth ;
> 'Tis but my tendrils that cling there,
> My roots are in the earth.

The aerial roots of Ivy are, in short, an arrangement by means of which the plant clings and climbs; and though it is doubtless true that they occasionally penetrate into the bark of trees, their object is not plunder, but the obtaining a more secure anchorage.

Of plants which attain to the dignity of trees, none perhaps exhibits such a prodigality of adventitious air-roots as the time-honoured Banyan (*Ficus indica*, p. 137). It is of this tree that Milton finely says :—

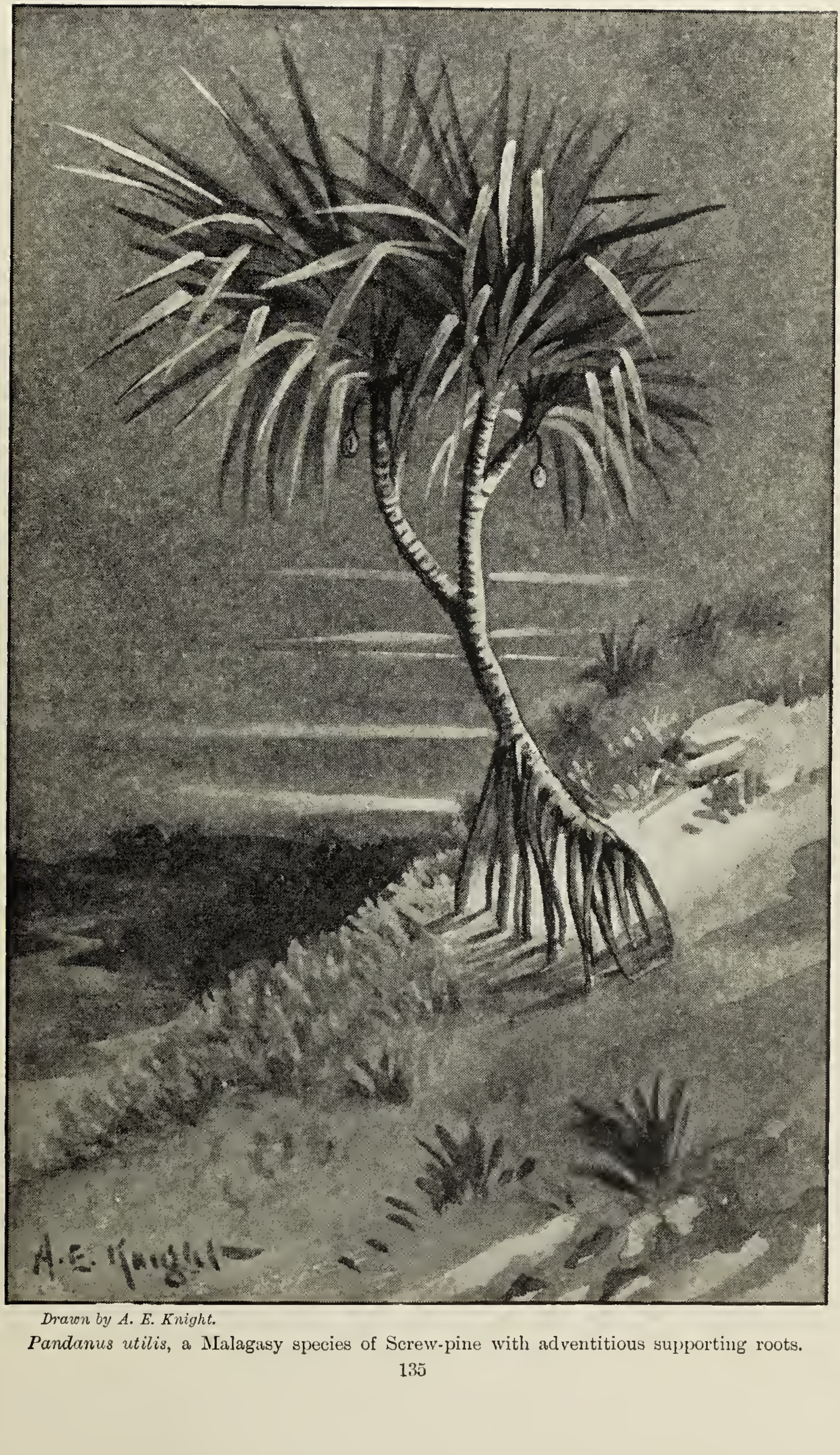
> The bended twigs take root, and daughters grow
> About the mother tree ; a pillared shade
> High over-arched, and echoing walks between.
> There oft the Indian herdsman, shunning heat,
> Shelters in cool, and tends his pasturing herds
> At loop-holes cut through thickest shade.

The parent tree, in fact, gives off aerial roots from its branches, as small tender fibres, which, increasing in length and thickness, presently reach the earth and pierce their way into it. The parts above-ground continue to grow thicker and thicker, till they attain the girth of large trunks, when they themselves become parent trees by sending out new branches from the top, and these in turn send down aerial roots, which undergo similar modifications and perform similar functions, till the original tree has become a grove! The vigorous growth of these trees may be gathered from the fact that one of their seeds, which had been deposited by a bird on the crown of a Palm-tree, not only began to germinate in that strange situation, but actually sent down a root through the stem of the Palm, thus destroying its host and supplanting it!

Apropos of this subject, we must say a word or two about the parasitical vagaries of the Brazilian Balsam-tree (*? Clusia rosea*), with handsome pink and white flowers and large shining leaves, which is thus referred to by Dr. Wallace: "It grows not only as a good-sized tree out of the ground, but is also parasitical on almost every other forest tree. Its large round whitish fruits are called 'cebola braba' (wild onion) by the natives, and are much eaten by birds, which thus probably convey the seed into the forks of lofty trees, where it seems most readily to take root in any little decaying vegetable matter, dung of birds, etc., that may be there; and when it arrives at such a size as to require more nourishment than it can there obtain, it sends down long shoots [? aerial roots] to the ground, which take root, and grow into a new stem. At Nazaré there is a tree by the roadside, out of the fork of which grows a large Mucujá Palm, and on the Palm are three or four young Clusia-trees, which no doubt have *Orchideæ* and Ferns again growing upon them." If we suppose (and the supposition is not extravagant) that these Ferns, at the time when Dr. Wallace visited the spot, supported and nourished on their fronds some creeping Moss-plants or Liverworts, we shall then have a four-ranked succession of guest plants—parasites on parasites, and on these parasites, and again parasites on them! Strictly speaking, however, these are instances of epiphytism rather than of parasitism, as the plants in question do not, like true parasites, derive food from their supporters. But we use popular language.

Mr. James Rodway has much to say of the Clusias and their deadly work. "Woe betide the forest giant when he falls into the clutches of the Clusia or fig," he writes. "Its seed being provided with a pulp, which is very pleasant to the taste of a great number of birds, is carried from tree to tree and deposited on the branches. Here it germinates, the leafy stem rising upward and the roots flowing, as it were, down the trunk until they reach the soil. At first these aerial roots are soft and delicate, with apparently no more power for evil than so many small streams of pitch, which they resemble in their slowly flowing motion downward. Here and there they branch, especially if an obstruction is met with, when the stream either changes its course or divides to right and left. Meanwhile, leafy branches have been developed, which push themselves through the canopy above and get into the light, where their growth is enormously accelerated. As this takes place the roots have generally reached the ground and begun to draw sustenance from below to strengthen the whole plant. Then comes a wonderful development. The hitherto soft aerial roots begin to harden and spread wider and wider, throwing out side branches which flow into and amalgamate with each other until the whole tree-trunk is bound with a series of irregular living hoops.

"The strangler is now ready for its deadly work. The forest giant, like all exogens, must have room to increase in girth, and here he is bound by cords which are stronger than iron bands. Like an athlete he tries to expand and burst his fetters, and if they were rigid he might succeed. But the strangler is like a python, and almost seems as if provided with muscles. The bark between every interlacing bulges



Drawn by A. E. Knight.

Pandanus utilis, a Malagasy species of Screw-pine with adventitious supporting roots.

out and even tries to overlap, but the monster has taken every precaution against this by making its bands very numerous and wide. We can almost see the struggle, and knowing what will be the result, must pity the victim.

"As the tree becomes weaker, its leaves begin to fall, and this gives more room for its foe. Soon the strangler expands itself into a great bush, almost as large as the mass of branches and foliage it has effaced. Its glossy leaves shine in the sunlight, and it seems to glory in its work. Every branch is clean and sleek; not a lichen or fungus can find shelter anywhere. It has got on the shoulders of the forest giant, but does not intend to support in its turn even the tiniest dwarf. If we could forget its murderous work, how we should admire it! Take the *Clusia insignis*, for example. Here we have one of the most beautiful shrubs in the world. Its thick leathery leaves shine as if polished, and its green sleek branches always look clean and healthy. As it sits crowing, as it were, over its victim, the contrast between them is most striking. Perhaps the forest giant is dying—the few leaves remaining are yellow and sickly. No flowers have been produced for two or three seasons, and even the branches look shrivelled. There is not the least hope of recovery; it only remains, therefore, to submit to the inevitable, to die and give place to the strangler." Here again, however, we have no parasitism in the true sense—the Clusias are merely climbers; they strangle, but do not feed upon the trees which support them.

Aerial roots, unless they are epiphytal, are usually more or less spherical in section, though they are liable to flatten out in growth if they are of the nature of clinging or supporting roots. Parasitic roots offer more variety, and may be rounded, flattened, wart-like, ribbed, disc-shaped, netted, etc., according to the special character of their work and the peculiarities of their environment. Some epiphytal Orchids, in addition to their white cord-like hanging roots, have others of a strap-like form, which adhere so firmly to the trunks of the host trees, that it has been found impossible to loosen one of the straps without tearing away a portion of the bark. "In other species of tropical Orchids,"* says Kerner, "the roots are not flat from the beginning, but become so when they come into contact with the bark. A root is often to be seen which arises as a cylindrical cord from the axis, then lays itself upon the bark in the form of a band, and farther on lifts itself once more, resuming at the same time the rope form. . . . Complete coalescence takes place between the bands and the bark, and the union is extremely close." It is affirmed by the same writer, that when the seeds of any of these tree-growing Orchids "are transferred to loose earth devoid of humus, they perish soon after

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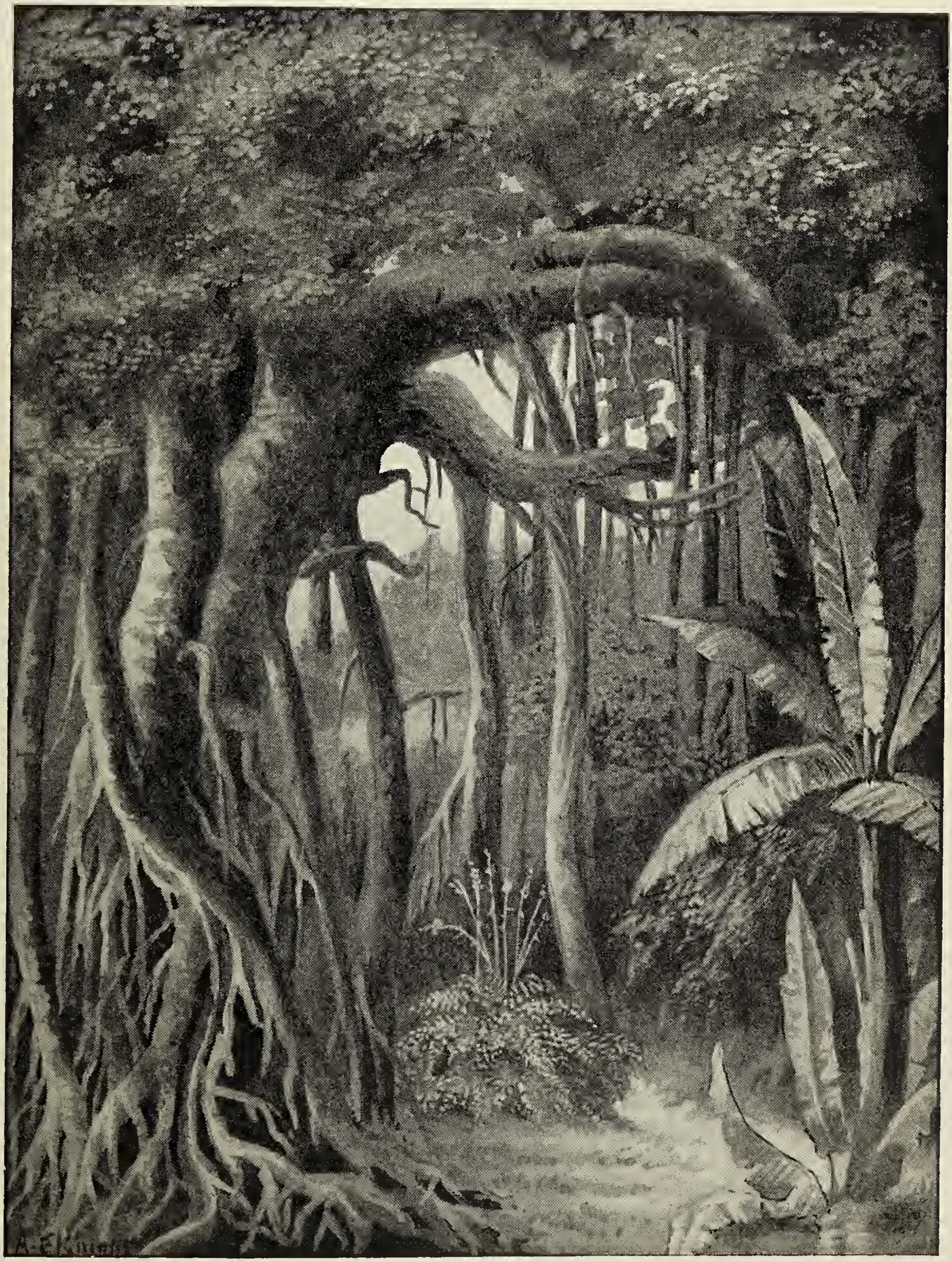
* *E.g.*, *Sarcanthus rostratus.*



Drawn by A. E. Knight.

Banyan-tree (*Ficus indica*) with aerial roots.

germination; whereas when sown on the bark of a tree, they not only germinate, but grow up with ease into hardy plants."

Many interesting cases are recorded of plants which, though in their normal state exhibiting no peculiarity of root growth like Banyan, Orchis, or Pandanus, yet have put forth adventitious roots from the most unlikely places when circumstances of an extraordinary nature made special demands upon their powers. It is affirmed of the Common Maple (*Acer campestre*) that if you plant it upside down the buried stem will put forth roots, and that the tree sustains no injury by such treatment. Not every plant is able to accommodate itself thus nicely to circumstances; yet there can be no doubt that a similar latent vegetative power exists in a great number of plants. Take the Silver Birch (*Betula alba*) for an example. Some sixty years ago one of these trees was blown down in the Birch wood of Culloden, "and fell," says a writer in *Science Gossip*, "right across a deep valley or ravine, which it completely spanned; and the top branches took root on the other side. From the parent stem no less than fifteen trees grew up perpendicularly all in a row"; and thirty years later, when the gentleman who furnishes these particulars visited the spot, they were still vigorous and flourishing. It is matter of common knowledge also, that the foliar organs of many plants possess the power of putting forth roots—a subject to which we shall refer more particularly when we come to speak of leaves.

It might be thought by those who are familiar with pictures of West Indian Mangrove swamps that the singular curved roots of those trees, standing high out of the water (p. 139), are adventitious; but the case is otherwise. They are true normal roots, resulting, curiously enough, from the germination of the seed while the fruit is still attached to the parent branches. "In the economy of Nature," says Dr. William Hamilton, "the Mangrove performs a most important part, wresting annually fresh portions of the land from the dominion of the ocean, and adding to the domain of man. This is effected in a twofold manner: by the progressive advance of their roots, and by the aerial germination of their seeds, which do not quit their lofty cradle till they have assumed the form of actual trees,* and drop into the water with their roots ready prepared to take possession of the mud, in advance of their parent stems."

An old English navigator—that able, trustworthy writer, William Dampier, thus describes the tree: "The red Mangrove groweth commonly by the seaside, or by rivers or creeks. It always grows out of many roots, about the bigness of a man's leg, some bigger, some less, which, at about six, eight, or ten feet above the ground, join into one trunk or body, that seems to be supported by so many artificial stakes. Where this sort

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* Hardly "trees." It would be more correct to say, "till they attained to a considerable size."

Drawn by A. E. Knight.

A Mangrove Swamp.

of tree grows it is impossible to march, by reason of these stakes, which grow so mixed one among another, that I have, when forced to go through them, gone half a mile and never set my foot on the ground, stepping from root to root." Kingsley describes a Mangrove swamp as a desolate pool, round which the Mangrove roots form an impenetrable net. As far as the eye can pierce into the tangled thicket, the roots interlace with each other, and arch down into the water in innumerable curves, by no means devoid of grace, but hideous just because they are impenetrable. The natives are quite at home in such places, however, leaping or climbing from root to root with ease and agility, though never daring to trust their weight on the treacherous marshy ground.

Many of the larger trees of India are famous for their buttress roots. Miss Gordon Cumming, who spent two years in Ceylon, was struck with the extraordinary size and height of these roots, which, as she says, "are thrown out on every side like buttresses, evidently to enable the trees to resist the rushing of floods. The buttresses are so high that full-grown men could stand in one compartment unseen by their neighbours in the next division." In the park of the Government Agent's house at Kurenegalla, Miss Cumming saw many majestic trees supported by their own wide-spreading roots, which covered the ground for a very wide radius, forming buttresses like low walls. "The most remarkable of these," she writes, "are the Koñ- and Labu-trees; there are also great Indiarubber-trees, whose roots, though not forming such high walls, are equally remarkable and labyrinthian."

The roots of the Lum-tree, a forest giant which grows on the island of Ualan, really deserve a place by themselves, and a special term would have to be invented to accurately describe their form. Dr. Hartwig considers them to be without a parallel in the Vegetable World. Each of the Lum-tree's roots runs above-ground to a considerable distance, and "is surmounted by a perfectly vertical crest, gradually diminishing in size as the root recedes from the trunk, but often three or even four feet high near the base. These crests, which are very thin but perfectly smooth, regularly follow all the sinuosities of the root, and thus form, for a considerable distance round the tree, a labyrinth of the strangest appearance. Large spaces of swampy ground are often covered with their windings, and it is no easy matter to walk on the sharp edges of their vertical bands, whose interstices are generally filled with deep mud. On being struck, the larger crests emit a deep sonorous sound, like that of a kettle-drum." These are not true aerial roots, nor even epigeous roots, but rather roots of a subterraneous origin, which have been pushed through the yielding oozy soil, or been washed bare by tropical rains.

CHAPTER VII

NATURE'S WOODCRAFT: A CHAPTER ON STEMS

Sap-laden stems, of forms grotesque and weird,
That creep, and climb, and twine, and hang in air.

WHAT is a *stem*? The term in popular language is confined to those parts of the plant which rise above the ground, but popular ideas are not always satisfactory or exact. We have seen that roots also may rise above the ground; and is not a tuber an instance of a stem which grows *beneath* the soil? The popular definition, then, will not answer. Of botanical definitions, Professor Thomé's is, perhaps, as satisfactory as any. "The stem, in its various forms," he says (*Lehrbuch*, p. 49), "is that part of the plant which bears the leaves, flowers, and fruits." This is, on the whole, a sufficient definition.

Before treating in detail of these "various forms," it would be well to make a few remarks on the structure of the stem. When dealing, on a former occasion, with the cells and vessels of plants, we named and described the three great classes into which all permanent tissues may be divided—viz., Fundamental or Ground Tissue, the Fibro-vascular System, and Epidermal Tissue; and we saw that each of these classes is represented in every well-developed foliage leaf. The annexed diagram (fig. 159*a*) has been prepared with the view of illustrating the manner in which these tissues and vessels are distributed through the stem of an ordinary dicotyledonous plant. The figure, indeed, represents an actual model which was made for us for lecture purposes, and which consists of a column of wax, not unlike an altar candle, but furnished with eight large wicks instead of one, the wicks being arranged in a circle, at about equal distances from each other. Fitting closely round the column is a cylinder of stout paper.

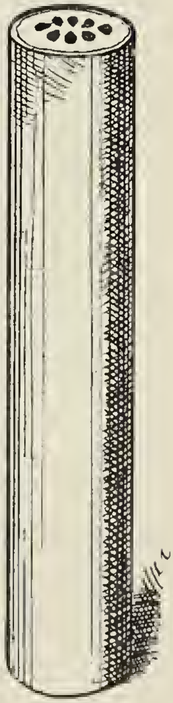
Fig. 159*a*.—Diagram to illustrate the arrangement of the fibro-vascular bundles in a dicotyledonous stem.

We will suppose that this column represents the erect and very young stem of a Flowering Plant—say a Sunflower stem; the paper cylinder surrounding it will then answer to the epidermis; the eight many-threaded wicks to eight separate fibro-vascular bundles; and the wax itself will represent the ground tissue. Bear in mind that the fibro-vascular bundles of the leaves are always in connection with the bundles of the stem, inso much that the latter are often regarded merely as lower portions of the leaf bundles; while a whole bundle formed by such union is said to be *common*—that is, common both to leaf and stem.

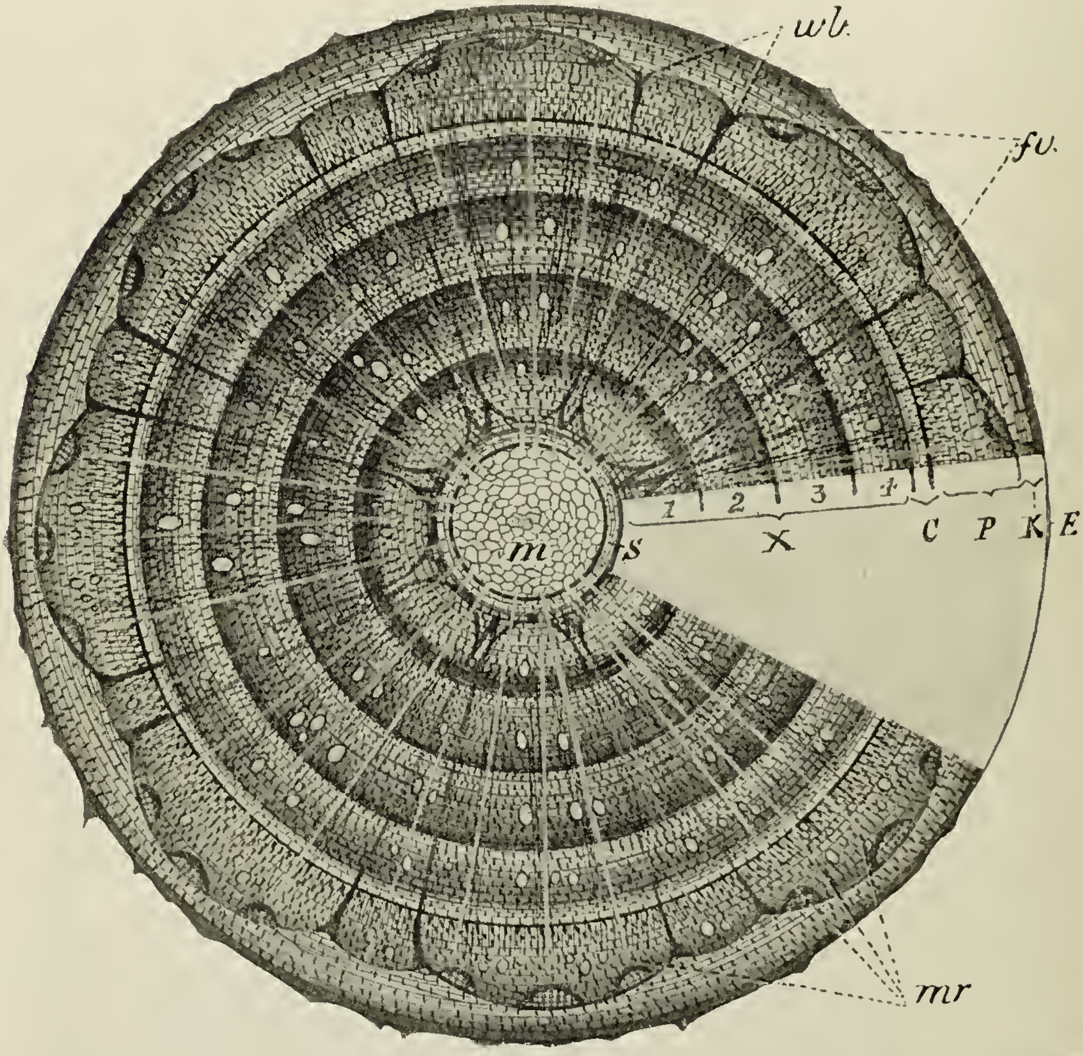

Fig. 160*a*.—Transverse section of a four-year-old dicotyledonous stem (diagrammatic). (*m*) Medulla or pith. (*mr*) Medullary rays. (*s*) Medullary sheath. (*X*) Xylem (wood). (*P*) Bast or phloëm. (*C*) Cambium ring. (*K*) Cortex. (*E*) Epidermis. The eight fibro-vascular bundles (*fv*) are united by wood and bast (*wb*) formed by the cambium between the bundles. The figures 1, 2, 3, 4, refer to the years of growth of the wood.

If it were possible for the wicks to increase continually in thickness, it is evident that they would at length meet, and form an unbroken circle round the innermost portion of the wax; and this is precisely what takes place with the woody bundles in the stems of dicotyledonous trees, such as the Oak, Beech, Elm, etc., though the completion of the circle is accelerated by the formation of new bundles between those already existing. The wood of timber-trees of several years' growth is nothing more than a mass of such bundles closely packed together, and surrounding that part of the ground tissue which is known as the *medulla*, or pith. Locked in as the pith then appears to be, communication is nevertheless maintained with the bark by means of narrow prolongations of the pith, which, in transverse sections of the stem, have the appearance of lines diverging from the centre. These, as having their rise in the medulla, are known as *medullary rays*. They constitute what cabinet-makers call the "silver grain" in wood.

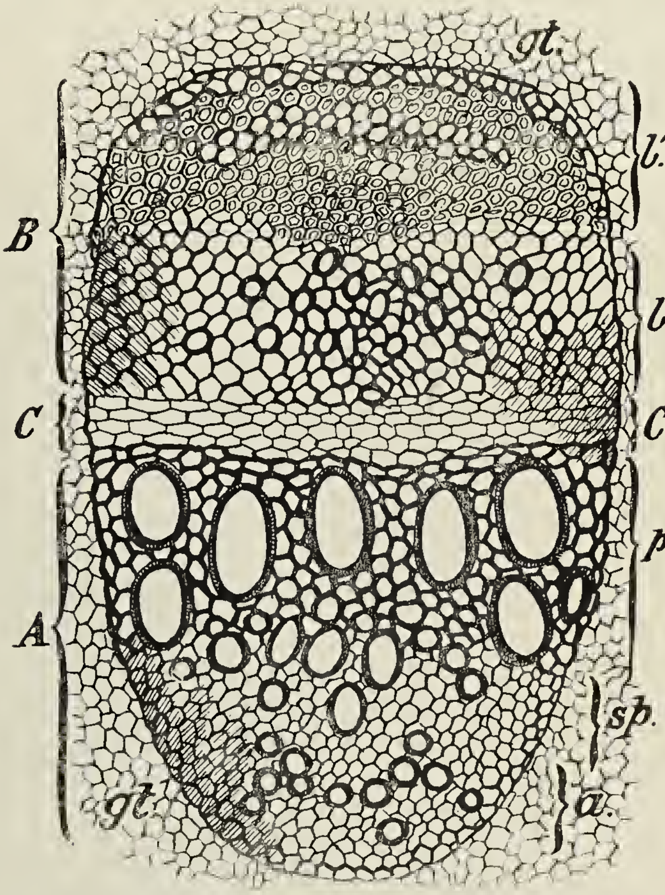

Fig. 161.—Transverse section of a fibro-vascular bundle of an herbaceous plant (diagrammatic). (*A*) Wood or xylem, consisting of (*a*) annular and (*sp*) spiral vessels surrounded by cells of the primary wood; and (*pv*) pitted vessels in the midst of denser woody cells. (*B*) Liber or phloëm, consisting of (*b'*) hard bast, and (*b''*) soft bast. (*C*) Cambium. (*gt*) Ground tissue.

But how do the woody bundles increase in size? The question is not easy to answer—at least, without bringing to our aid a good many technical terms—yet we do not despair of making the process plain. Here (fig. 161) is represented in transverse section a fibro-vascular bundle from the stem of an herbaceous plant; let us examine it. The narrow end, *A*, is that which, in a complete transverse section of the stem, would be directed towards the centre or pith, while the wide end, *B*, would of course be

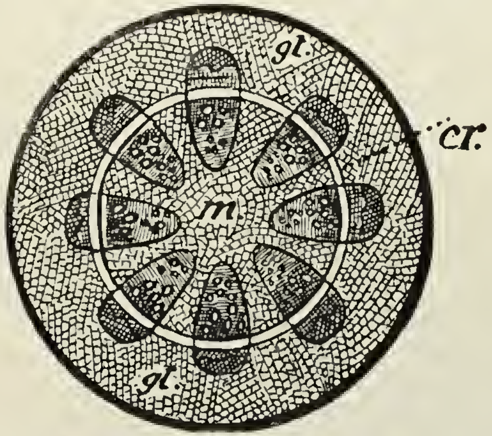

Fig. 162.—Transverse section of a dicotyledonous stem (diagrammatic). The eight fibro-vascular bundles are seen embedded in the ground tissue (*gt*). (*m*) Medulla or pith. (*cr*) Cambium ring.

nearest the bark (fig. 162). The whole bundle is embedded in ground tissue (*gt*). Now notice how the vessels are arranged in the bundle. Those adjoining the pith, and represented by darkly lined circles in the midst of other tissue, are annular vessels (*a*); immediately above them, embedded in similar (that is, woody) tissue, are spiral vessels (*sp*); and higher still are pitted vessels of various sizes (*pv*), surrounded by greatly thickened wood cells. Within the brackets lettered *C* we have a tissue of delicate growing cells known as the *cambium layer*; and above the cambium layer an assortment of sieve-tubes, bast-fibres, and parenchymatous wood-cells, of which the innermost constitute the *soft*, and the outermost the *hard bast*.

The soft, thin-walled, growing cells, or *cambium* (a name derived from the Latin *cambio*, I exchange), really divide the bundle into two parts, of which the inner (*A*) is called the wood or *xylem* (Greek *xūlon*, wood or timber), and the outer (*B*) the liber* or *phloëm* (Greek *phloios*, bark); and it is to these growing cells that all increase of the woody bundle is due. They are filled, indeed, with protoplasm, and in the growing season are constantly undergoing division to form new cells, by which means

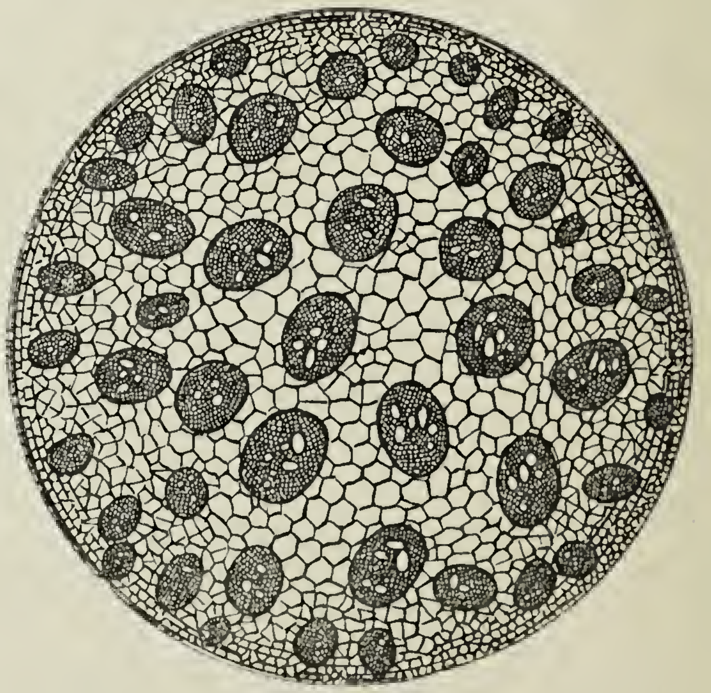

Fig. 163.—Transverse section of stem of Ravenna Grass—a monocotyledon—showing the closed fibro-vascular bundles embedded in ground tissue.

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* The name *liber* was applied by the Romans to the inner bark or rind of a tree used for paper. Our word "library" traces back to it.

new wood is added to the outside of the xylem, and new liber to the inside of the phloëm. All the woody bundles of the stem are, in a way, united by the cambium, which forms an unbroken ring in the stem, those portions of the ring which lie between the bundles being known as *interfascicular cambium* (fig. 162, *cr*). As the cambium remains dormant during the winter, and the cells which it forms in the spring are larger than those of the autumn, the extent of its work each year

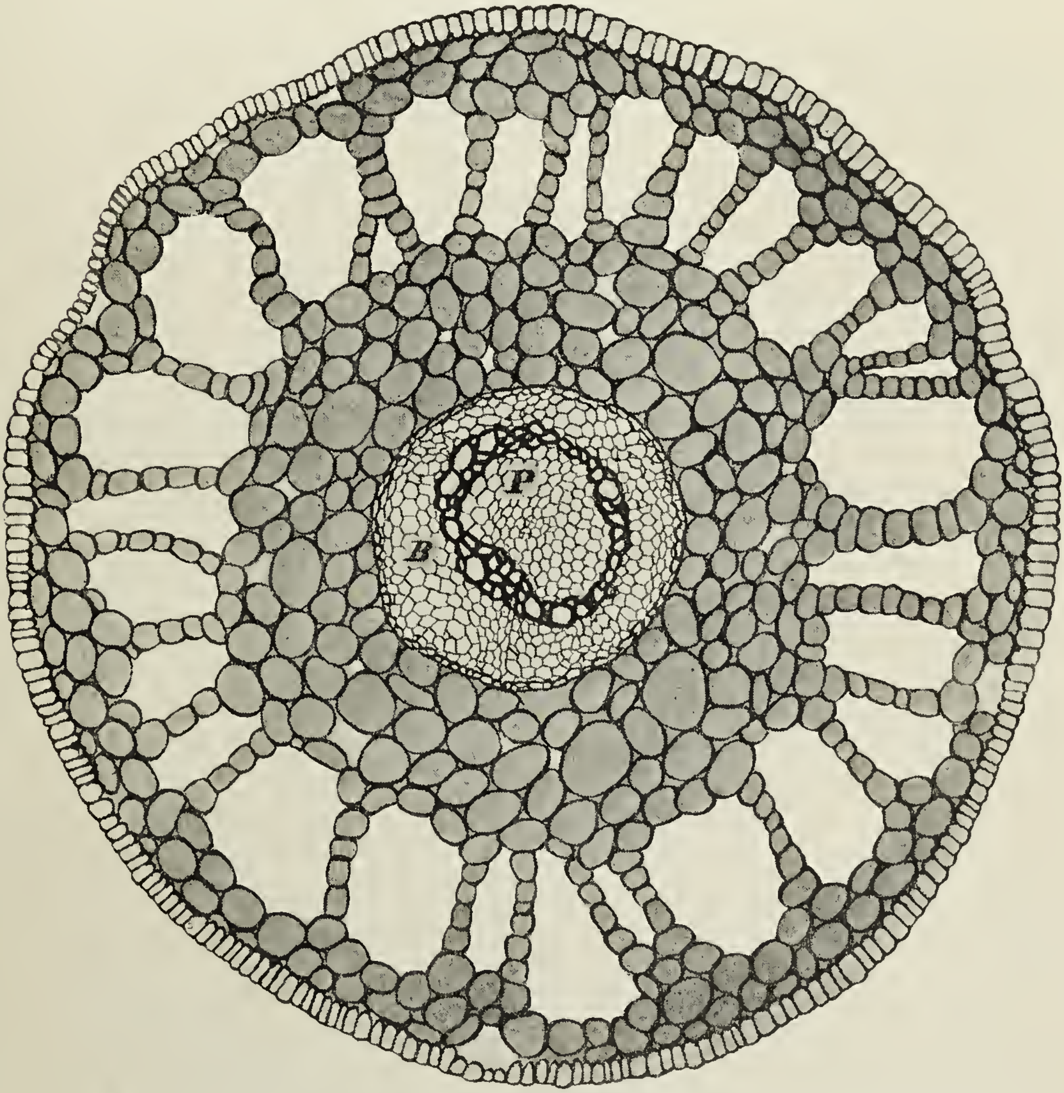

Fig. 164.—Transverse section of stem of Creeping Pillwort (*Pilularia globulifera*) with axial fibro-vascular strand. The parenchymatous tissue (*P*) immediately in the centre is surrounded by a ring of xylem (the darkly lined portion), outside of which is the bast (*B*) and a single layer of cells (the bundle sheath). The remainder of the section consists of cortex (the tinted portion), and epidermis (the outermost ring of cells).

may be easily traced—indeed, the concentric rings of wood in the trunk of a dicotyledonous tree are the abiding records of its annual and annular labours, and furnish means of forming a fairly accurate computation of the age of the tree. The interfascicular cambium serves the double purpose of lengthening the medullary rays (see p. 143) and adding fresh phloëm and xylem between the original bundles. In fact, it assists in completing the circles of the liber and wood, thus making the stem one solid whole.

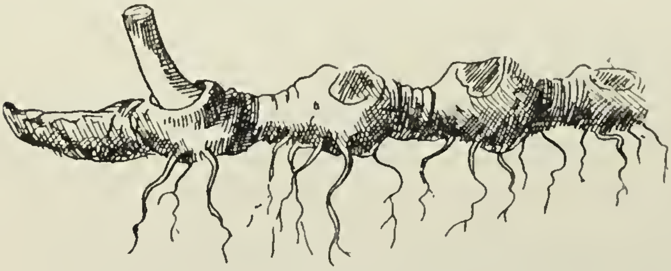
Fig. 165.—Rhizome of Solomon's Seal.

It should be added that all Flowering Plants do not have the fibro-vascular bundles arranged in the manner above described. In Monocotyledons—Palms, Lilies, Grasses, etc.—they are scattered irregularly in the stem; nor are these bundles provided with vitally active cambium; so that when they cease to grow (at an early stage in the history of the plant) the stem also ceases to increase in thickness. The section of a stem of Ravenna Grass (*Erianthus Ravennæ*), which is shown in fig. 163, contained a portion of one of these closed fibro-vascular bundles. Flower*less* Plants, or Cryptogams, usuallydo not contain them at all; but where they are present they sometimes form an irregular and broken ring near the outside of the stem, as in the Ferns, and in other cases constitute the axis of the stem, and are solitary. The Pillworts (*Pilularia*, fig. 164), a genus of aquatic plants specially partial to marshy and inundated ground, offer interesting examples of axial fibro-vascular bundles. All the Flowering Plants, and those among the cryptogams which have these bundles in their stems, also contain them in the roots; so that a system of vessels extends from root to leaves in each plant, and forms, as we were seeing in Chapter III., the skeleton or framework on which the plant is built up.

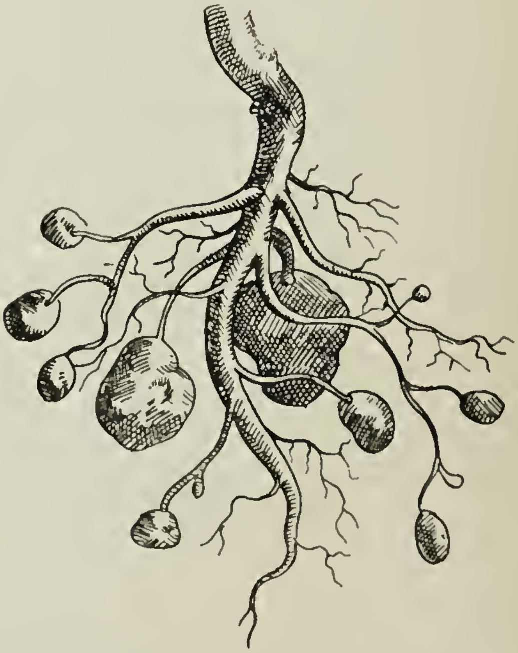
Fig. 166.—Underground stem of Potato-plant, showing tubers and root-fibres.

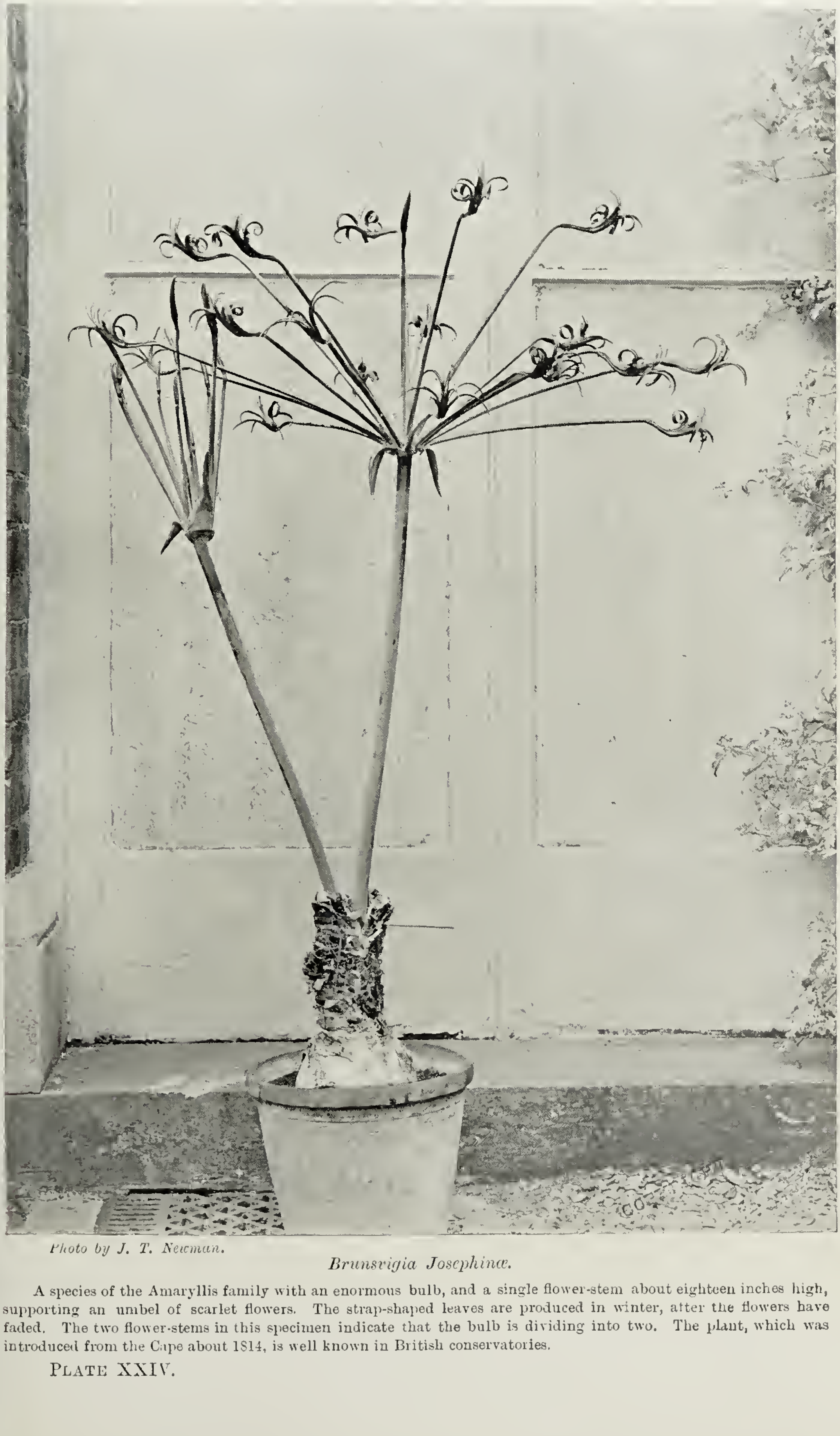

Photo by J. T. Newman.

Brunsvigia Josephinæ.

A species of the Amaryllis family with an enormous bulb, and a single flower-stem about eighteen inches high, supporting an umbel of scarlet flowers. The strap-shaped leaves are produced in winter, after the flowers have faded. The two flower-stems in this specimen indicate that the bulb is dividing into two. The plant, which was introduced from the Cape about 1814, is well known in British conservatories.

PLATE XXIV.

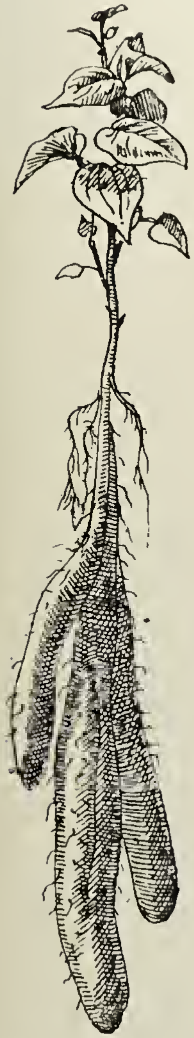

Fig. 167.—Chinese Yam.

The external forms of stems exhibit even greater variety than the external forms of roots. Some stems are very like roots, not in their forms merely, but also in their habits. We allude to those which grow underground—to rhizomes, tubers, bulbs, and corms.

Rhizomes, of which the Flag (*Iris*), Solomon's Seal (*Polygonatum*, fig. 165), and Lily of the Valley (*Convallaria majalis*) offer familiar examples, are subterranean stems of horizontal growth, which give off roots below and leaf- and flower-bearing shoots above. Such stems are always spoken of as roots by the old writers. Gerarde, for example, refers to the rhizome of the Iris as "gladen rotys" in the following curious recipe for a cosmetic: "Do take ij parties of the poudre of gladen rotys [Iris roots], and the iij part of the poudre of ellebre [Hellebore], that some men clepen cloffynge, and medele both these poudres togider in honey. A plaster of this wole purge and clense the face of frekels, also it will resolve the pockys and whelkys of the face."

Tubers are most conveniently studied in the Potato-plant (*Solanum tuberosum*, fig. 166). A potato is, in fact, a true stem, and its "eyes" are buds, each of which is capable of producing a new plant. Thomas Heriot (a fellow-voyager of Sir Walter Raleigh, who was the first to introduce the potato into this country) describes the tubers as "round, some as large as a walnut, others much larger. They grow in damp soils, many hanging together as if fixed on ropes." The Jerusalem Artichoke (*Helianthus tuberosus*) and the Chinese Yam (*Dioscorea Batatas*, fig. 167) are other familiar examples of edible tubers.

Bulbs are subterranean stems not unlike buds, with thick, fleshy scales folded round a conical axis (fig. 168). *Corms* are somewhat similar, but their scales are thin, few, and membranous; and the axis of a corm is much thicker

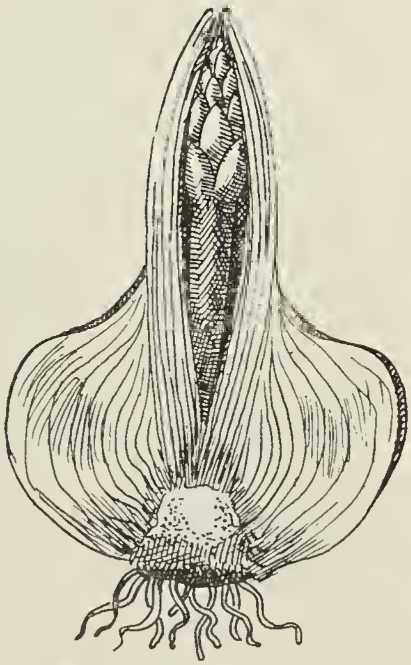

Fig. 168.—Bulb of Common Hyacinth (*Hyacinthus orientalis*) in section.

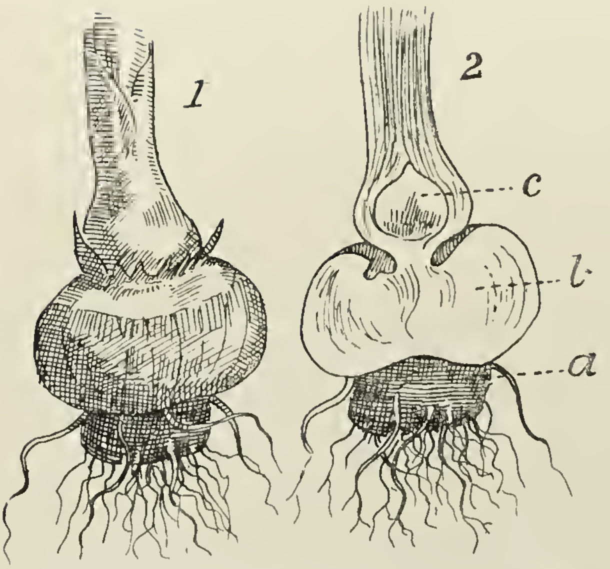

Fig. 169.—Corm of Saffron Crocus (*Crocus sativus*). 1. Whole corm. 2. Same in section. (*a*) Old corm. (*b*) New corm. (*c*) Bud.

than the axis of a bulb (fig. 169). The Crocus, Cyclamen, and Gladiolus offer good examples of the corm; and instances of bulbs are furnished by the Lily, Onion, and Hyacinth. Both these forms of underground stem are storehouses of food material, husbanding the strength and energy acquired by the plant during one season for the exigencies of the next. The reserve of food is largely drawn upon by the plant at the time of flowering, but if flowering be prevented, a very considerable saving of expenditure is the result; while the bulb, which is continually receiving fresh supplies of nutriment from the leaves, is found to be larger at the end of the growing season than at the commencement. A Lily, or other bulbous plant, by having the scape cut down year after year just before the period of flowering, accumulates an abnormal quantity of food-material (starch); and when at last the plant is permitted to flower, it is able to compensate itself for former deprivements by making an exceptionally grand display. Herein lies the secret of the size and beauty of many "florists' flowers."

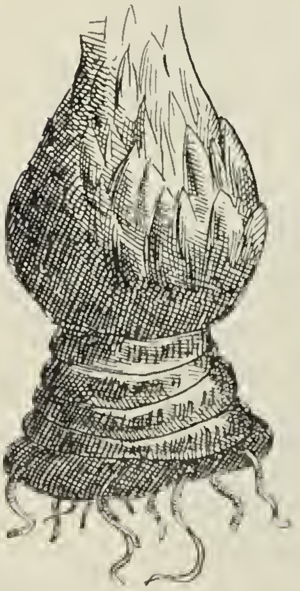

Fig. 170.—Corm of *Babiana sulphurea*.

Among certain plants with underground stems a kind of motion occurs, to which it may be worth while to make a brief allusion. Some Orchids, for example, appear one season in a spot at a little distance from that which they occupied in the previous season, and thus appear to travel, the shifting of position being effected by means of the sucker-like subterranean stems annually formed by the parent, which projects them to a certain distance and then perishes. The corms of many plants of the Iris order (*Iridaceæ*) exhibit a similar property, each forming a new corm at its apex every year, which feeds upon the parent till the latter is quite dry (fig. 169). Growth goes on in this way, year by year; the corms continually rising, not, indeed, "by stepping-stones of their dead selves," but by stepping-stones of their dead *parents*, "to higher things," till the surface of the earth is reached. Then the corms become dispersed, and each in its new position sends a thick shoot deep into the soil, through which the material of the above-ground corm is conveyed to form a new one at a suitable depth.

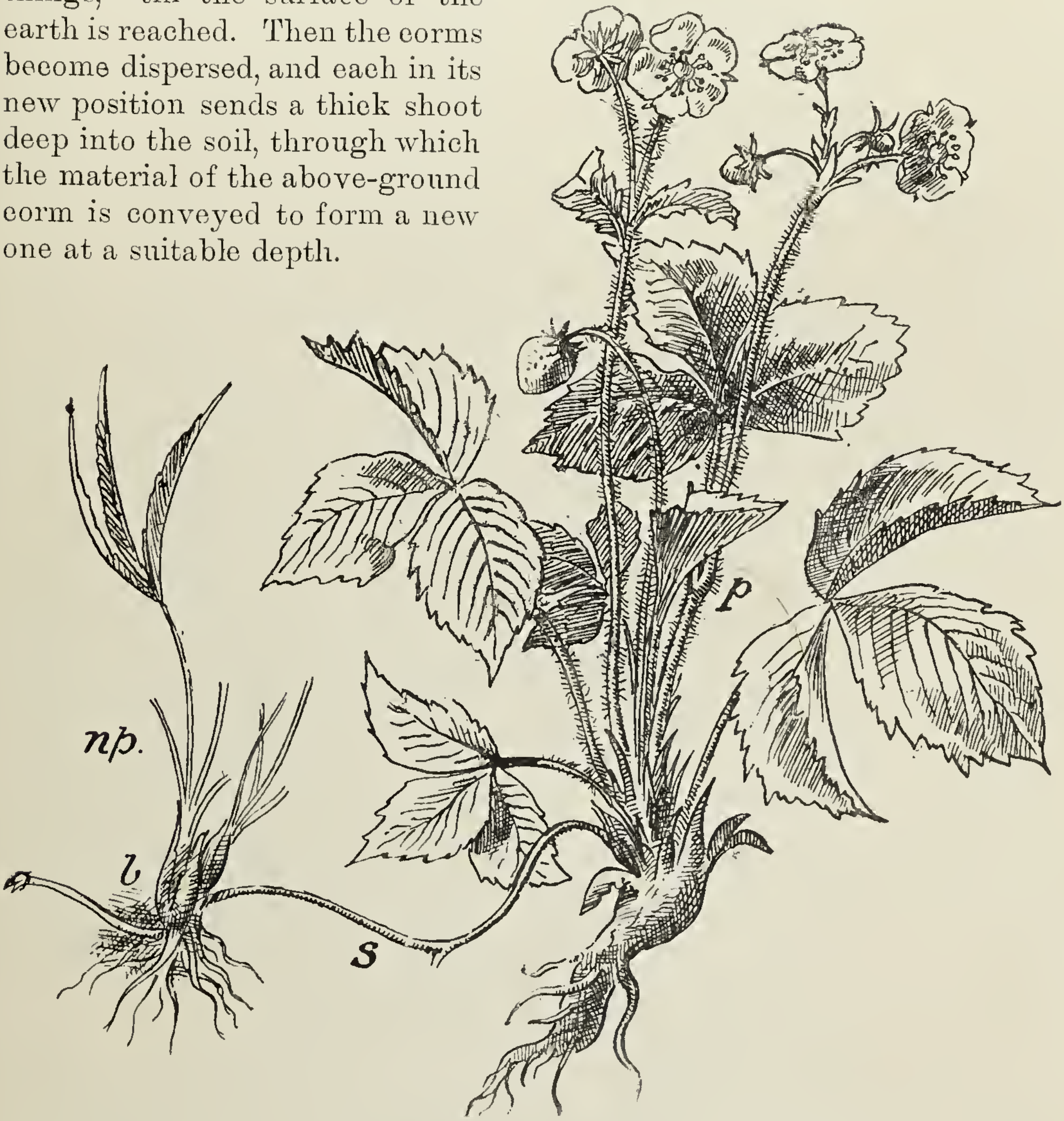

Fig. 171.—Wild Strawberry (*Fragaria vesca*). (*p*) Old plant. (*s*) Stolon or runner. (*np*) New plant. (*b*) Bud-scales of new plant.

Yet the above instances of vegetable progression have, after all, nothing very remarkable about them, the so-called motion being strictly analogous to the progression of an ordinary aerial stem by the formation of fresh branches year after year. True motion does, however, exist in a large number of above-ground stems, such as the tips of the runners or *stolons* of the Strawberry-plant (*Fragaria*,

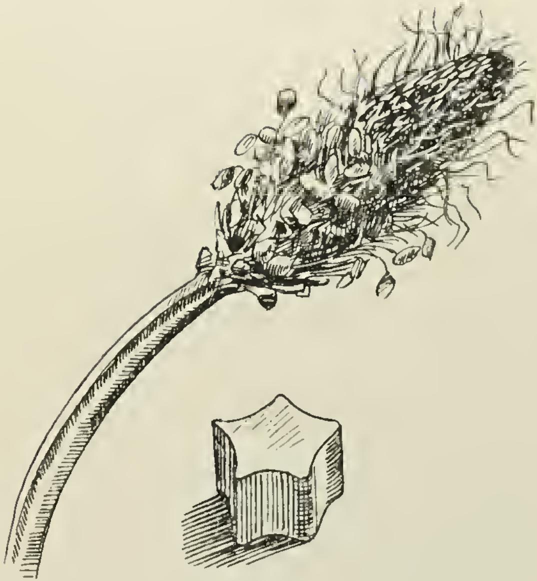

Fig. 172.—Angular stem of Ribwort Plantain (*Plantago lanceolata*).

fig. 171) and the growing points of the stems of the Ivy (*Hedera*), Raspberry (*Rubus Idæus*), etc., which Darwin, Sachs, and others have observed to rotate just as do the cotyledons and rootlets of the Bean (*Vicia Faba*), Pea (*Pisum sativum*), Wood-sorrel (*Oxalis Acetosella*), etc. Circumnutation is, indeed, a *general* characteristic of aerial stems.

Aerial stems present a far greater variety of forms than those which grow beneath the soil. In some cases the trunk is simple and unbranched, as in the Palms, when it is called a *caudex*; in others—to wit, the stems of most woody trees and shrubs—the branches are numerous. A stem that is weak and not woody, and which perishes annually down to the root, is *herbaceous*. Then there are root-shaped stems and knotted stems; ascending stems and trailing stems; twining stems and climbing stems; and all these may—and *do*—assume a bewildering diversity of forms—cylindrical, triangular, quadrangular, ribbed, compressed, etc. (figs. 172–174). How singular, for example, is the mode of growth of those glorious tropical climbers, the Bauhinias! Here (fig. 175) is a drawing of part of the stem of a Demeraran species, which the natives call "bush-rope" and the sailors "land-turtles' ladders," and which offers as neat an example of Nature's wood-carving as one could wish to see. It is probable that the undulating central part of such stems protects the sap-conducting tissues of the plants against strain. The edges of the stem are almost straight, and form a sort of framework to

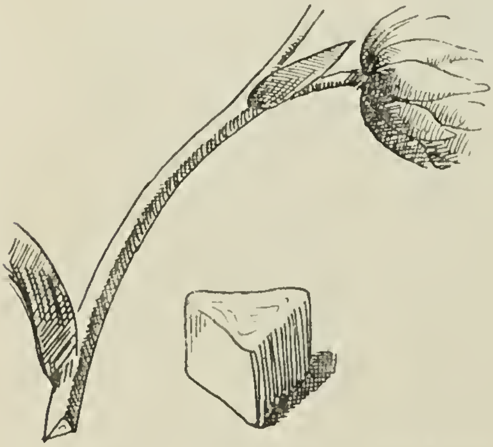

Fig. 173.—Triangular stem of *Carex atrata*.

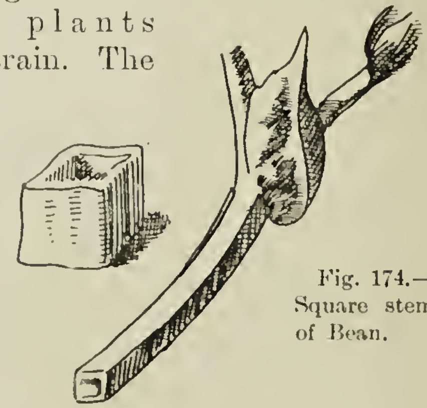

Fig. 174.—Square stem of Bean.

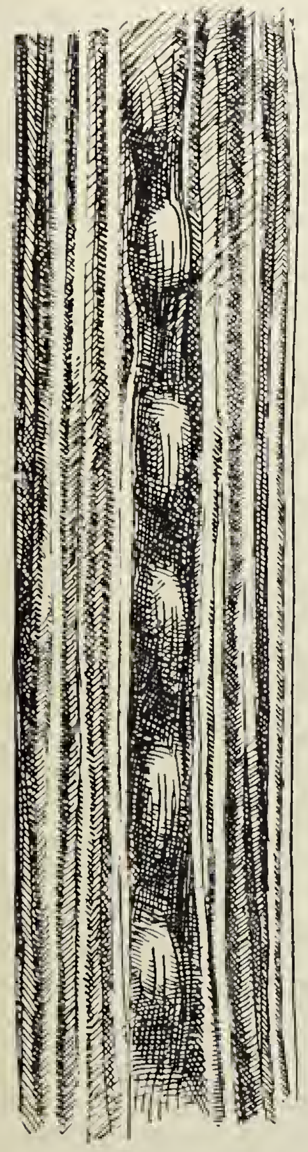

Fig. 175.—"Bush-rope": stem of a Bauhinia (Demerara). From a specimen preserved at Kew.

the sinuous middle part; so that, as Kerner says, "in the case of a longitudinal tension the frame only is affected at first," and "the tissues in the centre can still uninterruptedly conduct the sap to and from the branches which arise from its broad surface" (*Natural History of Plants*). "Often three or four of these bush-ropes," says Dr. Hartwig, "join tree to tree, and branch to branch; others descending from on high take root as soon as their extremity touches the ground, and appear like shrouds and stays supporting the mainmast of a line-of-battle ship; while others send out parallel, oblique, horizontal, and perpendicular shoots in all directions. Frequently trees above a hundred feet high, up-rooted by the storm, are stopped in their fall by these amazing cables of Nature, and are thus enabled to send forth vigorous shoots, though far from their perpendicular, with their trunks inclined to every degree from the meridian to the horizon. Their heads remain firmly supported by the bush-ropes; many of their roots soon refix themselves in the earth, and frequently a strong shoot will sprout out perpendicularly from near the root of the reclined trunk, and in time become a stately tree."

The Buttress-trees of the virgin forests of Central America, again, have very peculiar stems. They are provided, as their name implies, with buttresses from six inches to a foot thick, which project from the stems like walls to a distance of several feet, thus affording room for a comfortable hut in the angle between them. Then there are the Pao-Barringudos of the Brazilian forests, whose stems bulge out in the middle like enormous barrels; and the Delabecheas or Bottle-trees of tropical Australia, which have the same lumpish

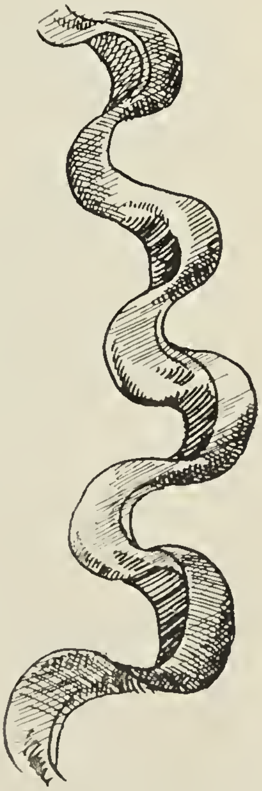

Fig. 176.—Portion of the corrugated stem of a Bauhinia. From a specimen preserved at Kew Gardens.

mode of growth (fig. 177), to say nothing of the *Caulotretus* or Monkey-ladders, and the numberless other tropical tree-climbers, whose singular varieties of stem-form—flattened and warty, ridged and contorted, net-like and interlacing—are the wonder of travellers. We shall return to some of these tropical curiosities presently when considering the means by which slender and weak-stemmed plants maintain an erect position.

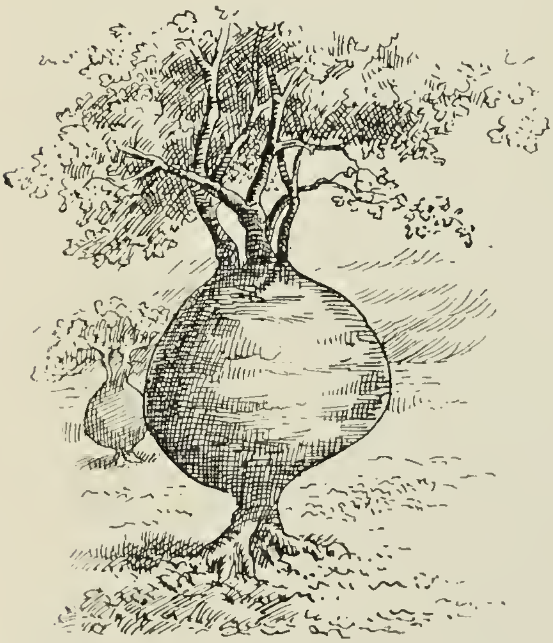

Fig. 177.—Bottle-tree (*Delabechea*) of tropical Australia.

Mention was made a moment ago of "woody trees and shrubs," an expression which recalls the old and somewhat vague classification of Flowering Plants into herbs, shrubs, and trees. Botanists differ very considerably in their definitions of these three forms, and it is hardly necessary to discuss the points of difference; probably most persons have a tolerably correct idea of the main distinctions upon which the classification is based. *Herbs* are plants of comparatively small size, usually with soft and succulent stems, which die down to their base every year. The crown or root-stock itself may survive, and produce either a fresh plant year after year, when the herb is said to be *perennial*, or only the following year, and then it is *biennial*. If the herb dies completely—roots and all—in the first year, it is an *annual*. Perennial plants with branching *woody* stems, which do not attain to the dignity of trees, or, in other words, do not exceed about twenty feet in height, are *shrubs*; while perennials of larger growth, if characterised by a distinct primary stem or trunk, may be fairly classed among *trees*. No hard-and-fast dividing lines can be drawn between these three forms, however, herbs passing into shrubs, and shrubs into trees, by endless gradations.

It may be remarked in this connection that the modifying effect of climate on the size of plants of the same genus, and even of the same species, is in some cases extremely curious. Heat is a great stimulus to growth, and many plants which attain to the dignity of trees in tropical and sub-tropical countries will degenerate into mere shrubs when grown in more temperate regions. Speaking generally, the farther north we go the more stunted is the vegetation; but the difference observable in plants of the same species even when growing in neighbouring countries is frequently very marked. A striking illustration of the above facts is afforded by the Willows (*Salix*), which in this country are timber-trees of considerable dimensions, while in the Arctic regions they seldom attain the height of *nine inches*! *Salix herbacea*, *myrtilloides*, *pyrenaica*, and *reticulata*, all species found in the ice-regions of North America, arrive at maturity and bear their flower-catkins when they are scarcely six inches above the ground!

To come back to the stem. The points on the stem where leaves are given off and buds formed are called *nodes*; the spaces between, *internodes* (fig. 178). Recently Professor L. Celakovsky, of Prague, has propounded a new theory respecting the building up of the stem. As just stated, the view formerly held by botanists was that the internode consisted of all that section of the stem lying between two nodes, but in Celakovsky's opinion this view requires some qualification when applied to dicotyledons. According to a notice of this theory by W. C. W[orsdell] in the *New Phytologist*, the Bohemian botanist divides stems into two classes—*holocyclic* and *mericyclic*. Holocyclic stems consist of a series of joints or internodes placed one above another, each occupying the entire diameter of the axis and terminating at the node in a leaf. As each leaf arises from that portion of the apex which becomes the stem-joint to which it belongs, we may regard, he says, the leaf along with the latter as a morphological unity, and term it a *Sprossglied* (shoot segment). The entire monocotyledonous embryo (apart from the root) represents a first such *Sprossglied*, the hypocotyl being its holocyclic *Stengelglied* (stem-joint). Holocyclic articulation is characteristic of monocotyledons. The mericyclic stem differs materially from the holocyclic, the stem-joints or internodes being arranged *side by side* (juxtaposed) as well as superposed; and therefore occupy only a portion of the diameter. Thus, in the case of leaves arranged spirally on a stem, the internode is only a segment of the diameter extending from one leaf to that which comes exactly above or below it. This arrangement of leaves is made clear in the next chapter, but for our present purpose it may be said that according to the number of leaves in one complete turn of the spiral round the stem, so there is a corresponding number of segments or internodes juxtaposed in its diameter, and all beginning on different levels. When the leaves form a whorl, as in the Bedstraws (*Galium*) and Woodruff (*Asperula*),

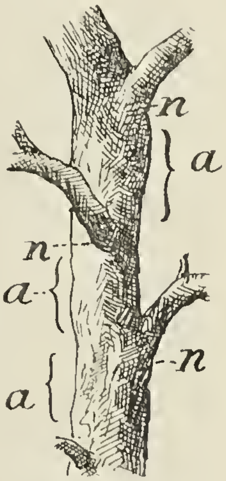

Fig. 178—Stem of leaf branches. (*n*) Nodes. (*a*) Internodes.

there will be as many internodes as leaves, but all beginning and ending at the same level. We cannot go into all the details here; but we may say in brief that whereas the former theory of Braun and Sachs regarded the stem as a pre-existing basis on which the leaf is developed, Celakovsky holds with Fleischer and Hegelmaier that the leaf is first formed and develops from its base a *Stengelglied* or internode.

A hollow and unbranched stem, the internodes of which are separated by thickened nodes, as in the Grasses, is a *culm* (fig. 179); while a pithy stem without thickened nodes is a *calamus*. We have good examples of this sort of stem in the Rushes (fig. 180). Our English Grasses, it must be confessed, give but a poor idea of the dignity of a culm, and one must make a journey to India, or South China, or the Eastern Archipelago, where the colossal *Bambuseæ* (Bamboos) abound, in order to obtain a truer idea. Every one of those polished jointed stems is a culm. Sometimes as many as a hundred of them "spring from a single root, not seldom as thick as a man, and towering to a height of eighty or a hundred feet" (Hartwig). Miss Gordon Cumming tells us that in Ceylon these giant Grasses "peep above ground during the rains, about July, and shoot up at the rate of twelve inches in twenty-four hours. The Malacca Bamboo [*Bambusa maxima*], which is the largest known species, continues growing till it attains a height sometimes considerably above a hundred feet, with an average diameter of nine inches." Picture for a moment the grace of our meadow Grasses, united with the lordly growth of the Italian Poplar (*Populus nigra*), and we shall have a faint idea of the beauty and dignity of this form of stem.

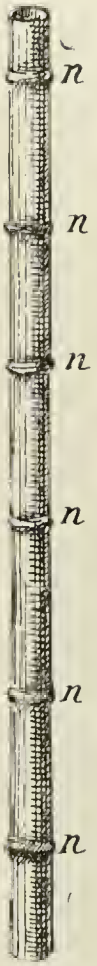

Fig. 179. — Portion of the culm of a Bamboo. (*n*) The thickened nodes.

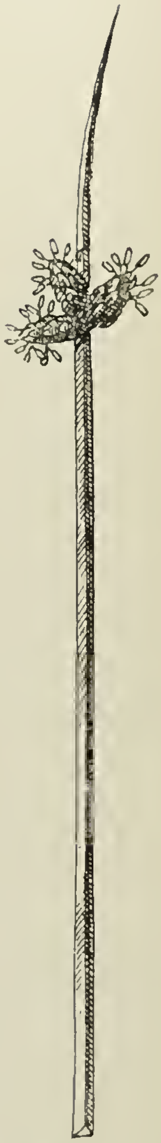

Fig. 180.—Portion of the triangular stem or calamus of a Club Rush (*Scirpus pungens*) with flowers.

Branches occasionally take remarkable and misleading forms. The dark green leaf-like expansions of the Butcher's Broom (*Ruscus aculeatus*) are really branches—flattened branches or *cladodes*—on which the little greenish flower is borne. This is one of the most curious of our native plants, and the only woody monocotyledon indigenous to British soil. In the southern half of Britain it is common locally in woods where the

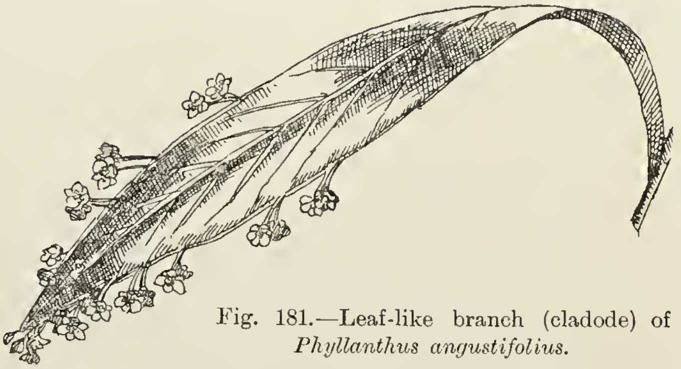

Fig. 181.—Leaf-like branch (cladode) of *Phyllanthus angustifolius.*

surface soil is sand or gravel, and on windy heathlands one is pretty sure to meet with it. The cladode shown in fig. 181 is not a cladode of the Butcher's Broom, but of a Jamaica shrub, *Phyllanthus angustifolius*, which belongs to quite another family and order. There is also a small genus of evergreen shrubs, consisting of only four species, which bears its flowers in much the same manner; indeed, they have received on that account the appropriate name of *Phyllocladus*, from the Greek *phullon*, leaf, and *klados*, a branch. They belong to the Cone-bearing order (*Coniferæ*) and are natives of Borneo and New Zealand. Somewhat analogous to the leaf branches of this family are the flat two-edged membranous branches of the Arrow-jointed Genista (*G. sagittalis*, fig. 182), a not uncommon plant in English gardens.

Branches which are arrested in their growth to form hard points are known as *thorns* or *spines*. Thus the thorns of the May-tree (*Cratægus Oxyacantha*, fig. 183), Blackthorn (*Prunus spinosa*), Spiny Rest-harrow (*Ononis spinosa*), etc., are simply metamorphosed branches; for they contain, like true branches, fibro-vascular bundles. Under cultivation the thorns disappear, and fruitful branches are borne in their stead; a fact which suggests the interesting inquiry, What is the purpose of thorns in the economy of Nature? Dr. Burnett offered an ingenious answer to this question upwards of sixty years ago, though possibly even he is indebted for the thought to a still earlier botanist. "In open tracts of country, the very circumstance of the sterility of the soil must prevent the production of many plants; and of those which grow, few will be enabled to perfect many seeds. It is necessary, therefore, to protect such as are produced from extermination by the browsing of cattle, otherwise not only would the progeny be cancelled, but also the present generation be cut off. And what more beautiful and simple expedient could have been devised than ordaining that the very barrenness of the soil, which precludes the abundant generation by seed, should at the very same time, and by the very same means, render the abortive buds (abortive for the production of fruit) a defensive armour to protect the individual plant, and to guard the scantier crop which the half-starved stem can bear? That such an armature is produced by the abortion or partial development of buds and branches, there is abundant proof. For not only are thorns found in every stage, varying from their simple dormant or winter state, when, if opened, they contain the rudiments of leaves, through leaf-bearing spines to rigid thorns on the one hand, or leaf-clad branches on the other; but the very organs, *i.e.*, buds, which, when the plant is half-starved, are partly developed as spines, and partly only as branches, become, when an abundant supply of nourishment is provided, altogether leafy branches; the buds have all been wholly developed, none have degenerated into thorns, and the plant is tamed. The Common Rest-harrow (*Ononis arvensis*) is a familiar example immediately in point, for of it there are two well-known varieties called *O. spinosa* and *O. inermis*, from the circumstance of this being smooth and destitute of thorns, while that is covered with them. These two varieties I have often seen growing together on the same heath; the one well-clad with its offensive and defensive arms, and furnished with few leaves to tempt the appetite of cattle; the others, upon or near to which a careless cow had dropped a profusion of manure, replete with leaves and blossoms, but wholly destitute of thorns, and just in such a state as to furnish an agreeable repast to the animal by which it had been so richly endowed."

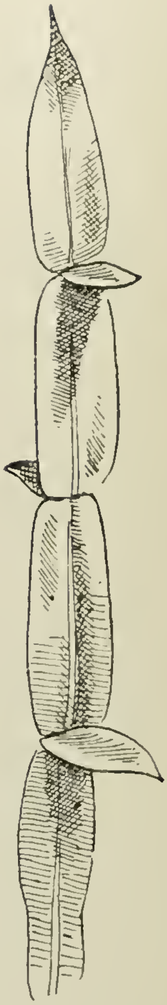
Fig. 182.—Two-edged membranous branch of *Genista sagittalis*.

The wonderful way in which stems seem able to adapt themselves to circumstances, terrene, climatic, and otherwise, is even more strikingly illustrated in the tropical Spurges (*Euphorbiaceæ*). These adopt the forms and habits of the *Cacteæ*, an order of plants from which they are widely separated, developing the same succulent tissue (a provision against rainless seasons), a tough leathery membrane to retard evaporation, and formidable spines as a protection from browsing cattle. Sometimes these spines get into the breasts of buffaloes and other large animals, causing inflammation and even death, and the wild asses of the desert are often lamed by them. Compare the stems of the two species of African Spurge (*Euphorbia grandicornis* and *E. abyssinica*) shown in figs. 184 and 185 with the slender European species (*Euphorbia spinosa*, fig. 186).

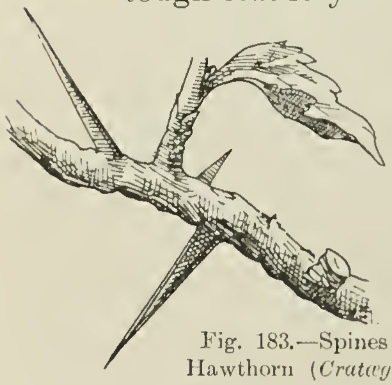
Fig. 183.—Spines of Hawthorn (*Cratægus Oxyacantha*).

Weak-stemmed plants, which object to the low earth-trailing life that satisfies a Strawberry-plant or Creeping Buttercup, resort to all manners of devices in order to grow upwards. Thus the Ivy (*Hedera Helix*) climbs by means of its short and multitudinous aerial roots—it is a *root-climber*; the Bramble (*Rubus fruticosus*)—a *hook climber*—develops prickles on its stem, whose bent points enable the plant to cling to whatever will help its ascent; the Traveller's Joy (*Clematis Vitalba*) and Garden Nasturtium (*Tropæolum majus*)—*leaf climbers* both—gain the desired end by means of their leaf-stalks, which they twist round the nearest support; the Vine (*Vitis vinifera*) and Virginia Creeper (*Vitis quinquefolia*) mount upwards by help of tendrils, which, in the plants named, are metamorphosed branches with adhesive discs, but in others—as the Sweet Pea (*Lathyrus odoratus*), Yellow Vetchling (*L. Aphaca*), *Smilax*, and (possibly) White Bryony (*Bryonia dioica*)—are metamorphosed leaves and stipules.* *Ercilla volubilis*, a Chilian climber, attaches itself to any available support by means of adhesive discs borne directly upon the branches just above the axils of the leaves. Lastly, the stem itself may entwine the supporting object, when its spiral course is in some plants always to the left (*e.g.*, the Convolvulus), in others always to the right, as the Hop (*Humulus Lupulus*), albeit external conditions have no influence on the maintenance of these directions. The climbing proclivities of the Hop are greatly facilitated by the development of innumerable anvil-shaped hooks on the ridges of its hexagonal branches.

Plants whose shoots twine always to the right—*i.e.*, clockwise—are called *dextrorse climbers*; while those whose shoots take the opposite direction—*i.e.*, counter-clockwise—are described as *sinistrorse climbers*. "It is a matter of indifference to the direction of these movements," says Kerner, "whether we allow light, warmth, or humidity to operate on this side or that; the particular species always twists in the same direction, the Hop towards the right, the Convolvulus towards the left. More than this, even if the twining portion is continuously bound in an opposite direction, the result is all the same; the plant cannot be

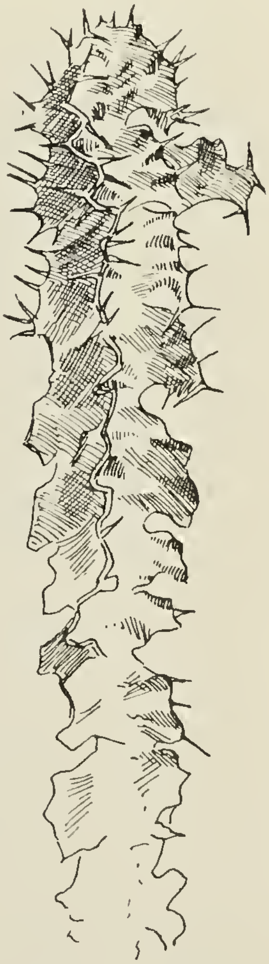

Fig. 184.—*Euphorbia grandicornis* (South Africa).

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* Some are of opinion that the so-called climbing stipules of the Bryony are really extra-axillary branches.

coerced into any other path, and will not depart from the direction peculiar to it. It continues to twist and twine according to an innate tendency inherited from generation to generation, and we can only refer the different directions of twisting to internal causes, to the peculiar constitution of the living protoplasm in each particular plant." It has been asserted that the Bittersweet (*Solanum Dulcamara*) is both a left-handed and a right-handed climber, but we are not aware that the assertion is based upon any accurate observation. Kerner, however, affirms that in many species of climbing plants whose stems, like that of the Bittersweet, increase in thickness from year to year, "the twining is not very conspicuous," and adds of the plant in question that it forms a kind of link "between plants with twining and those with interweaving stems."

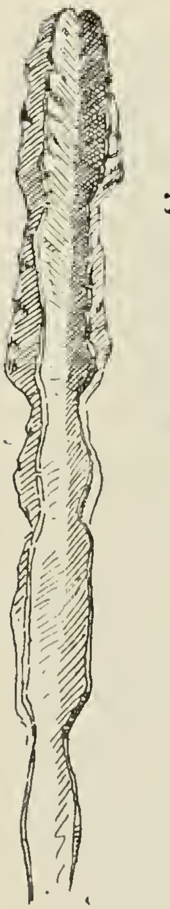

Fig. 185.—*E. abyssinica* (Abyssinia): about fourteen feet high.

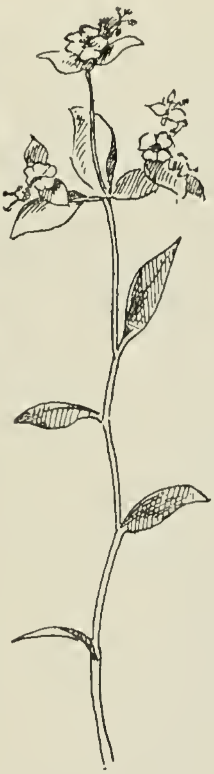

Fig. 186.—*E. spinosa* (Europe).

Travellers tell us that we must go abroad in order to obtain just ideas of the habits and eccentricities of climbing and twining plants; and the accounts which they bring us from the far-off forests of the Amazon and West Indies, from India and the South Pacific Islands, are well calculated to kindle a desire to go thither. They tell us of foot-tangling Mamures,* with creeping stems and fan-shaped leaves, which interlace with wire-like branches of other plants hanging from above. "You look up and around, and then you find that the air is full of wires, that are hung up in a network of fine branches to half a dozen different sorts of young trees, and intertwined with as many different species of slender creepers. You thought at your first glance among the tree-stems that you were looking through open air; you find that you are looking through a labyrinth of wire-rigging, and must use the cutlass right and left at every five steps" (Kingsley). Some of these climbers are "twisted in strands like cables; others have thick stems contorted in every variety of shape, entwining snake-like round the tree-trunks, or forming gigantic loops and coils among the larger branches; others, again, are of zig-zag shape, or indented, like the steps of a staircase, sweeping from the ground to a giddy height" (Bates).

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* *Carludovica*, a genus of monocotyledonous plants, most of which are climbing and palm-like, and all of which are tropical. The genus is included in the order *Cyclanthaceæ*.

Herb disputes with herb, shrub with shrub, and tree with tree, for every cubic foot of air and soil. It is one grand struggle for existence.* Nor do the weakest always go to the wall. By employing artifice the slender clinging plant sometimes destroys the strong-limbed self-supporting giant; the unfittest rather than the fittest thus surviving in the struggle. This is well illustrated in the Marcgravias, and particularly in *Marcgravia umbellata*, which abounds in the woods of Jamaica, and which assumes such a variety of forms in the process of growth that it is often mistaken for different plants. At its first appearance it is but a poor, thin, weak-stemmed climber, bearing a few heart-shaped leaves; but it is also provided with aerial roots, and by means of these it attaches itself to the sturdy trunk of any tree that is conveniently contiguous, and mounts and mounts through the dense leafy gloom of the forest till it reaches some region of unobstructed light, overtopping the foliage of the tree by which it climbed. With that it changes its tactics, the whole plant being transformed as by the touch of a magician's wand. The stem rapidly strengthens and increases in size, flattening and moulding itself over the larger branches of its supporter; and presently it sends down numerous slender, dependent, and individual branches from the upper part, at the same time throwing off its now useless leaves and roots. Last of all, the plant separates from its host—leaving the tree perhaps in a dying state—and becomes a self-supporting withy shrub, capable of producing flowers and nectar, and, in due season, abundance of ripe fruit.

Another extraordinary climber is one of the Climbing Palms. "Though no thicker than your finger, it will be found," says Mr. P. H. Gosse in *Omphalos*, "almost a quarter of a mile in length. This is a kind of Cane (*Calamus* †); its slender jointed and polished stem is encased in the closely sheathing and tubular bases of the leaves, which are spiny on their midribs, spiny on their pinnæ, and horridly spiny on the long and tough whip-lash in which the point of each leaf terminates. This lengthened cord is studded, at intervals of a few inches, with whorls of stout and acute prickles which are hooked backwards, and perform an important part in the economy of the plant. We see how it sprawls along the ground a few yards, then climbs up a tree, runs over the summit, descends on the opposite side to the ground, mounts over another tree, and thus pursues its worm-like course. Now as the pinnate leaves are put forth at every joint, the formidably armed flagellum affords a secure hold-fast to the climbing stem, which otherwise would be liable to be blown prostrate by the first gust of wind; the recurved hooks, however, catch in the leaves and twigs of the trees, and effectually maintain the domination of the prickly intruder."

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* An Indian Grass—*Panicum arborescens*—whose stem is no thicker than a goose-quill, rises as high as the tallest trees in this contest for light and air.

† The *Calami* supply most of the walking-canes of commerce, of which some twenty millions, valued at about £40,000, are annually imported. Mr. Gosse was a careful observer, but "almost a quarter of a mile" is a surprising length for any of these Calami. The statement needs confirmation.

Writing of a forest in the interior of Shag Island, in the Hauraki Gulf, four miles from the mainland of New Zealand, Froude, the historian, says: "We turned from the path into the forest, forcing our way with difficulty through the thicket. Suddenly we came on a spot where three-quarters of an acre, or an acre, stood bare of any kind of undergrowth, but arched over by the interwoven branches of four or five gigantic Pokutukama-trees, whose trunks stood as the columns of a natural hall or temple. The ground was dusty and hard, *without trace of vegetation.* The roots twisted and coiled over it like a nest of knotted pythons; while other pythons, the Rata parasites [*Metrosideros robusta*] wreathed themselves round the vast stems, twined up among the boughs, and disappeared among the leaves. It was like the horrid shade of some Druids' grove." "Without trace of vegetation"—those words are significant. Though the statement is a negative one, it tells of a warfare of vegetation, too—but a warfare that is accomplished. The victors are the Pokutukama-trees and the Ratas, which alone survive. How many youthful plants—Blackwood-trees, Ti-trees, Acacias, Tree-ferns, and so forth—have been crushed out of being by these vegetable pythons!

The same fierce struggle for existence is well exemplified in the Mora-trees (*Mora excelsa*) of Guiana, of which Waterton has left an impressive picture: "The Wild Fig-tree (*Ficus*), as large as a common English Apple-tree, often rears itself from one of the thick branches of the *Mora*, and when its fruit is ripe, to it the birds resort for nourishment. It was to an undigested seed passing through the body of this bird, which had perched on the *Mora*, that the Fig-tree owed its elevated station there. The sap of the *Mora* raised it into full bearing;* but now, in its turn, it is doomed to contribute a portion of its sap and juices towards the growth of different species of Vines, the seeds of which the birds also deposited on its branches. These soon vegetate and bear fruit in great quantities; so, what with their usurpation of the resources of the Fig-tree, and the Fig-tree of the *Mora*, the *Mora*, unable to support a charge which Nature never intended it should, languishes and dies under its burden; and then the Fig-tree and its usurping progeny of Vines, receiving no more succour from their late foster-parent, droop and perish in their turn."

To much the same purpose speaks a recent traveller, Mr. James

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* This statement needs confirmation. We are not aware that the *Ficus* is a parasite.

Rodway. Species of *Loranthaceæ*—the Mistletoe family—propagated by birds, are parasitic on the forest trees of Guiana. "As the parasite gets strong, its long extensions spread from branch to branch, and from twig to twig, everywhere extending octopus-like arms provided with sucking-discs, which adhere to and bleed the tree in a hundred different places. Branch after branch is dried up, but as the loranth has many strings to his bow, this does not hurt him much. There are always more to conquer, and unless the tree stands alone, which is, of course, impossible in the forest, he rarely comes to grief. It is not to his advantage that the tree should die quickly, and therefore the longer it can support him the better. However, even the most sturdy giant of the forest suffers greatly from such continual depletion, and may be so weakened as to lag behind in the race for life, with the ultimate result that it is smothered by its fellows."

Circumnutation, which has been shown to be so general in the growing ends of stems, is seen to excess in the climbing organs of weak-stemmed plants, and is the means by which they are enabled to feel about (if one may so say) in search of support. Thus the apex of the stem of a Hop-plant (*Humulus Lupulus*), fourteen inches in length, has been known to sweep round in a circle nineteen inches in diameter in quest of something to lay hold of, and the long shoot of a tropical *Asclepiad*, observed by Darwin, beating this record, described a circle five feet in diameter. As the weather was hot, the plant was allowed to stand on the naturalist's study table, and he watched with interest the long shoot sweeping this grand circle, night and day, in search of some object round which to twine. *Ceropegia Sandersoni*, a closely allied plant (fig. 187), exhibits the same interesting phenomenon. The movement, which has received the name of *circumnutation*, is, indeed, related to, if not identical with, that which enables a shoot to climb upwards; a fact of which it is easy to satisfy oneself by bringing the circumnutating shoot of a Hop-plant in contact with any upright object that would serve as a support, when the shoot will at once begin to entwine about it. Kerner suggests that such movements may be caused by the action of co-operating protoplasts in certain rows of cells on the circumference of the shoot; though what it is that impels them to this work he does not pretend to say. To him it is "just as puzzling as the stimulus to the production of partition-walls in the interior of a cell"—and that, as we have shown, is one of the sealed mysteries of biological science.

We will conclude this chapter with some remarks on *the sizes of stems*. In prehistoric ages the Animal World had its giants both on land and sea, of which the rocks bear witness in the fossil remains of mastodon and pterodactylus, of plesiosaurus and ichythosaurus; but the Vegetable World has its giants *now*. Think of the Wellingtonias (*Sequoia*) of California, in their sheltered valleys five thousand feet above the level of the sea, with stems three hundred feet and more in height, and ninety, one hundred, or even a hundred and twenty feet in circumference. Think of the mighty Eucalyptus-trees of Western Australia, rising from the glens of the Warren River and the deep recesses of the Dandenong, and piercing the sky four and five hundred feet up—trees that might look down upon the spire of Strasburg Cathedral, or cast their shadows over the Great Pyramid![*] Think of the great Banyan-tree of the Nerbuddah, with its three hundred and twenty main trunks and three thousand smaller ones, covering an area of two thousand feet—a giant which shelters beneath its umbrageous arms a host of Custard-apple and other fruit trees. Think, too, of the Silk-cotton-trees (*Bombax Ceiba*) of Yucatan, with stems so large that in some cases fifteen men, with arms extended, can scarce embrace a single trunk; and of the lofty *Moras* of Guiana, of which, as we have seen, Waterton has left so vivid a picture. "Heedless and bankrupt in all curiosity must he be"—again we quote from the hero of the *Wanderings*—"who can journey through the forests of Guiana without stopping to take a view of the towering *Mora*. Its topmost branch, when naked with age, or dried by accident, is the favourite resort of the toucan. Many a time has this singular bird felt the shot faintly strike him from the gun of the fowler beneath, and owed his life to the distance betwixt them." Would that some of our English song-birds, growing scarcer amongst us every year, had trees as high to nest in!

The "Monster Cactus" which reached Kew Gardens in 1846 measured nine and a half feet in circumference and weighed a ton. Eight strong mules were required to draw it over the mountains of Mexico, and ten men to place it in the scales at the Royal Gardens (see p. 165). Considering that Cactuses are only succulent plants, these statistics are indeed astonishing.

The length attained by the fleshy stems of many Seaweeds may be referred to in this connection. One species of Sea-wrack, *Macrocystis pyrifera*, which abounds in the southern oceans between Tierra del Fuego and New Zealand, though its stalk is not thicker than a pen-holder, sometimes measures upwards of nine hundred feet in length; and *Lessonia*, another plant of the same interesting family (*Laminariaceæ*), attains to tree-like dimensions and has a stem as thick as a man's thigh. Probably the extraordinary length of some of these ocean Thallophytes is the originating cause of most fables about the sea-serpent. In the month of December, 1848, the ship *Peking* was passing near Moulmein in calm weather, when the son of the owner, and all the crew, saw, a distance away, something extraordinary balancing itself on the waves—apparently an animal of prodigious length. "With our telescopes," says the narrator, "we could from the *Peking* perfectly distinguish an enormous head, and a neck of monstrous size, covered with a mane, which alternately appeared and disappeared. Everybody agreed that it must be the great serpent." The captain took the resolution of making the closer acquaintance of this celebrated monster, and a boat was lowered. In due course the boat returned, bearing the creature in tow. It was quickly hauled on board, but being covered thickly with marine parasites of every species, some time elapsed before the discovery was made that the prize was neither more nor less than a huge *Alga*. It measured a hundred feet in length and four feet in diameter, the *thickness* being in this instance the most remarkable feature. What had been mistaken for a head was the root; while the motion communicated by the waves to the smooth snake-like stem had given the plant the semblance of life.

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[*] A Eucalyptus-tree measured by Froude, the historian, was forty-five feet round at the height of his shoulder (*Oceana*, p. 127).

To return for a moment to plants with woody stems. There is a Chestnut-tree (*Castanea vesca*) on Mount Etna, which measures a hundred and eighty feet in circumference; a Plane-tree (*Platanus orientalis*) near Constantinople with a *diameter* of nearly fifty feet; and Lime-trees (*Tilia*) in Lithuania with a girth of eighty-seven feet; though none of these offers anything remarkable in regard to height. They are dwarfs, indeed, beside the Eucalyptus-trees of Australia and the Wellingtonias of California. There are other venerable old Limes besides those of Lithuania. At Chalouse, in Switzerland, there stood one of these trees in Evelyn's time, "under which was a bower composed of its branches, capable of containing three hundred persons sitting at ease. It had a fountain set about with many tables formed only of the boughs, to which the ascent was by steps, all kept so accurately and so very thick, that the sun never looked into it" (Johns). Another famous member of the same family existed—perhaps still exists—at Neustadt, in Wurtemberg, whose huge limbs were supported by numerous stone columns.

But it is not size alone which makes a tree noteworthy, else would the tropical Tumboas or Welwitschias—well called *mirabilis* or "wonderful"—find no place of mention here (fig. 188). The Welwitschias are not, indeed, giants of the Vegetable World, but their stems are, none the less, curiosities. The first European discovery of the plant was made by Mr. C. J. Atkinson, who forwarded specimens to the Botanical Museum at Cape Town, but was otherwise rather reticent concerning the discovery. There was no occasion for reticence. *Welwitschia mirabilis* is an unique plant—a monotypic genus, indeed—totally unlike every other member of the Vegetable Kingdom, both in appearance and mode of growth, and therefore a plant to be taken account of.

Fortunately, within a few years of its discovery, the celebrated botanical traveller, Dr. Welwitsch, rediscovered it. While exploring the waste and arid deserts of South-West Tropical Africa, not far from Cape Negro, the doctor came upon a hard rough-looking disc, elevated some ten or twelve inches from the ground, and having a diameter of from three to four feet. It was the stem of a Tumboa. From deep grooves in the circumference of the stem, two opposite leaves—tough, brown, and torn into innumerable thongs—hung down and trailed, curling, along the sand to a distance of five or six feet in both directions. These were the true leaves.* It has since been discovered that only two such leaves are developed on every plant, and that they persist during the long life of the individual. The flowers (fig. 188), which resemble the cones of the Larch, spring up annually in crimson clusters round the edge of the disc, though the wood is of a stony hardness. The concentric layers which compose the stem show that growth in thickness takes place as in dicotyledons; but upward growth is arrested at an early period.

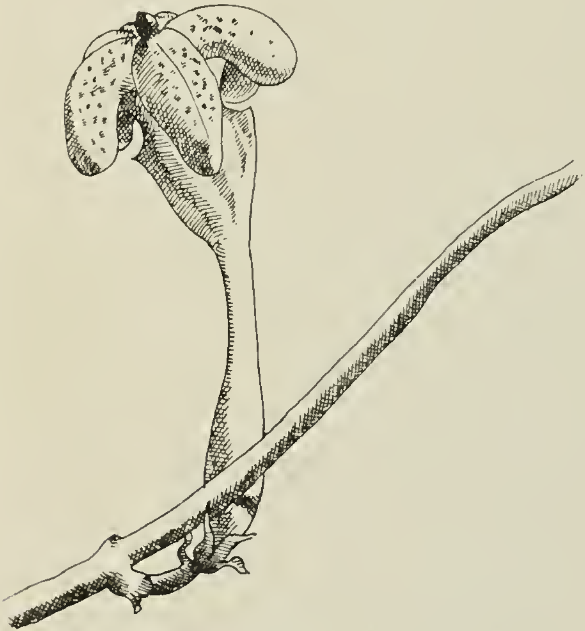
Fig. 187.—Flower of *Ceropegia Sandersoni.*

The age of many forest-trees is enormous. The great Chestnut of Tortworth is believed to have been a flourishing young sapling in the time of Egbert; an Oak in Normandy—the *chêne chapelle*—which was converted into a chapel some two centuries ago, was probably at that time seven hundred years old; while the famous Salcey Oak is probably much older than either, and the Winfarthing Oak (see p. 168) on the Earl of Albemarle's estate near Diss, in Norfolk, is perhaps more patriarchal still. But the Methuselah of the race, according to Mr. W. Senior, is the famous Greendale Oak at Welbeck, which is believed to have weathered the storms of fifteen centuries. About a hundred and fifty years ago this tree "was deprived of its heart by the eccentric desire of the then owner to make a tunnel through the trunk. This novel piece

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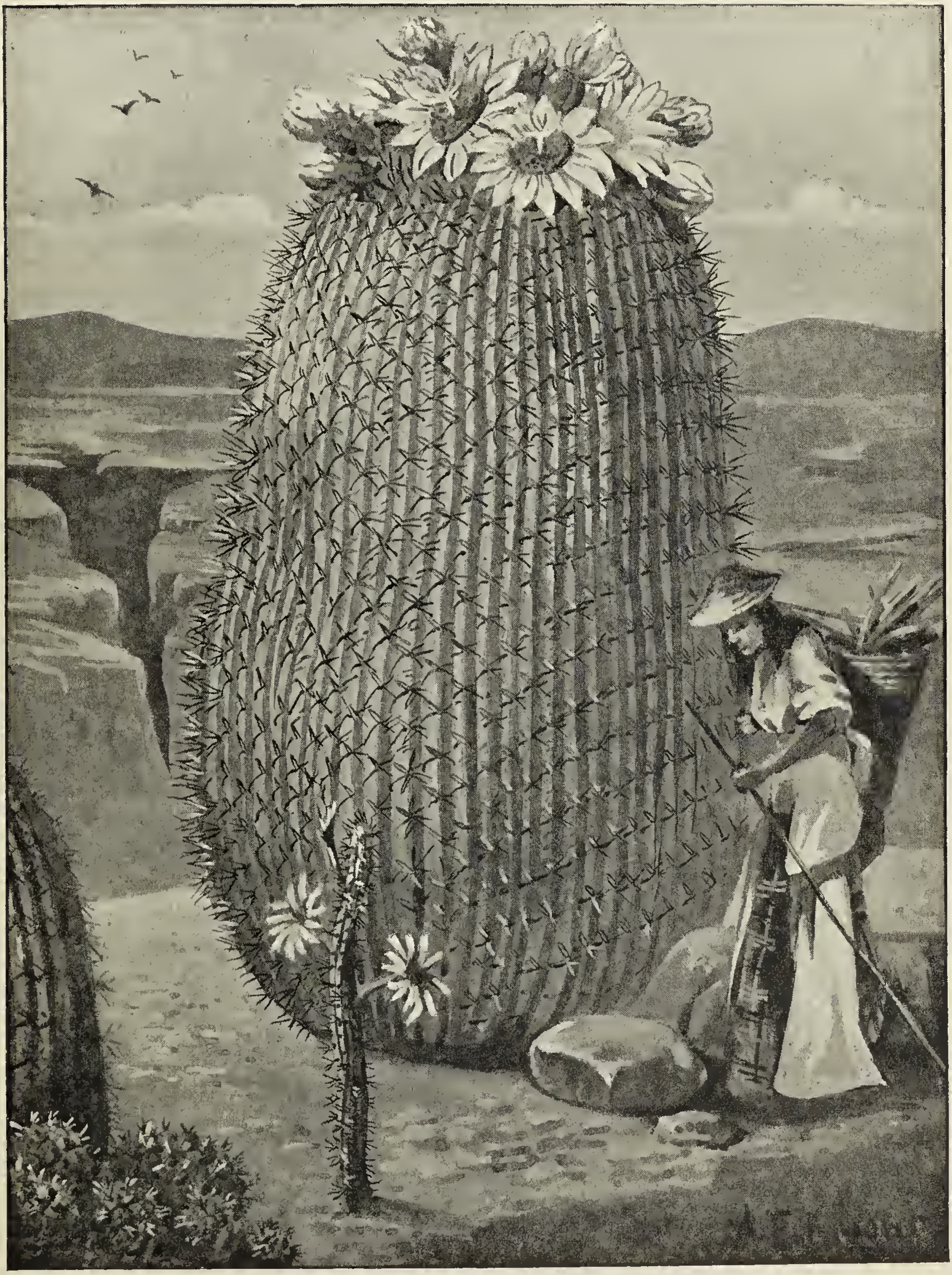
* Not the cotyledons, as was at first supposed. Two cotyledons are, indeed, produced, but they fall away while the plant is still quite young.



Drawn by Alfred E. Knight.

Monster Cactus from Mexico, exhibited in Kew Gardens in the year 1846.

of engineering was effected without any apparent injury to the tree. An opening was made through which a Duke of Portland drove a carriage and six horses, and three horsemen could ride abreast. The arch is 10 ft. 3 in. high, and 6 ft. 3 in. wide." The Greendale Oak has no longer the Cowthorpe Oak at Wetherby, in Yorkshire, as a competitor. This tree was reported to be in possession of "a few green leaves" so late as the year 1880, and was then thought to be about eighteen centuries old, but it is now a ruin. In 1776 its circumference three feet from the ground was forty-eight feet. The Winfarthing Oak, mentioned above, measured seventy feet in circumference at the base of its trunk in 1820, and, in the opinion of some judges, is quite as ancient as its Welbeck rival.

Nor are Oaks and Chestnuts the only trees famous for longevity. An Ivy (*Hedera Helix*) near Montpellier is (1903) nearly four hundred and fifty years old, and a Rose-tree at Hildesheim, in Germany, can be traced back to the time of Charlemagne. There are Cedars (*Cedrus Libani*) on Mount Lebanon from six hundred to eight hundred years old; and Lime-trees (*Tilia vulgaris*) near Friburg that have existed for 1,230 years. The Yew-trees (*Taxus baccata*) of Fountains Abbey are believed to have been in a flourishing condition twelve centuries ago; "the Olives (*Olea Oleaster*) in the Garden of Gethsemane were full-grown when the Saracens were expelled from Jerusalem; and a Cypress (*Cupressus sempervirens*) at Somma, in Lombardy, is said to have been a tree in the time of Julius Cæsar. Yet the sacred Bo-tree (*Ficus religiosa*) [at Anarajapoora] is older than the oldest of these by a century, and would almost seem to verify the prophecy pronounced when it was planted, that it would 'flourish and be green for ever.'" It was under a Bo-tree that Gautama reclined when he passed through the crisis of his ministry; and Buddhist superstition sees in that event the origin of the quivering of the Bo-tree's heart-shaped leaves. Even the patriarchal giant of Anarajapoora is not so ancient as the older Wellingtonias, however, some of which were lusty millenarians when that veteran was a baby!

Here let us pause, though not for want of matter to carry us farther. The topic, indeed, is inexhaustible. Even in a subject so apparently tame and dry as the stems of plants, how much there is to interest and inform! How infinite in variety, how wealthy in resource, how wonderful is Nature—whichever way we turn, on whatever class of objects we fix the eye! How many curious facts—morphological and biological—have been before us since we began! Glance back for a moment and consider a few of them. Recall a leading fact here and there. Think of the *structure* of a plant with reference only to leaf, root, and stem (for the flower as yet we have not reached); think of the millions of cells and vessels which compose it; of the provision for the upward and downward flow of sap; of its life-sustaining and life-destroying secretions; of the means by which its growth is effected. Think of the endless variety of external forms in root and stem; of the habits, metamorphoses, and motions of those organs; of their latent vegetative possibilities, their vigorous growth, their longevity. What lessons in patience and prudence, in thrift and economy, the plants could teach us! How sentient and wise they appear to be—how steady and methodical—how provident for the future plant! Poets would even persuade us that they have passions like ourselves—envies and jealousies, loves and antipathies; and one almost wonders at times if the thought is only fanciful. But we are treading on forbidden ground. Excursions into the realm of Fancy are impermissible in a sober treatise on Botany.

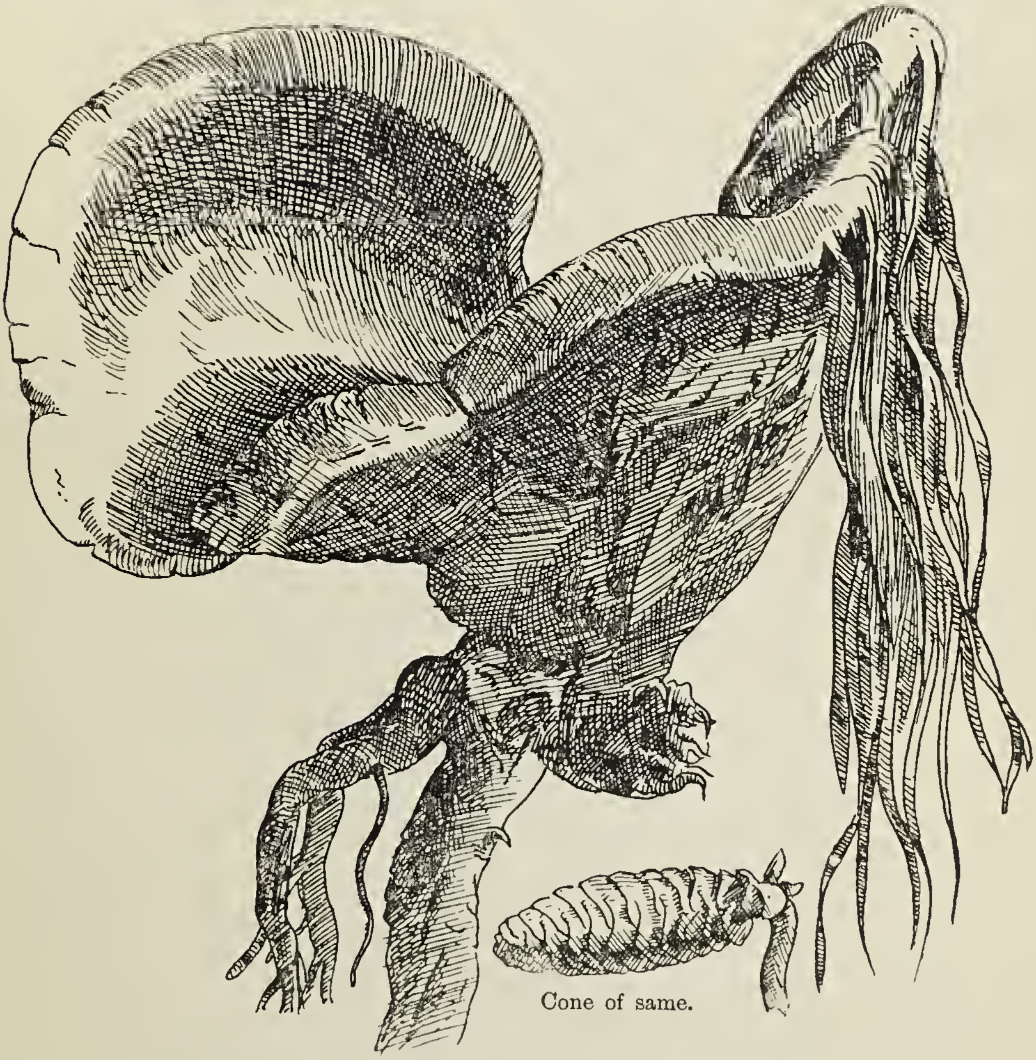

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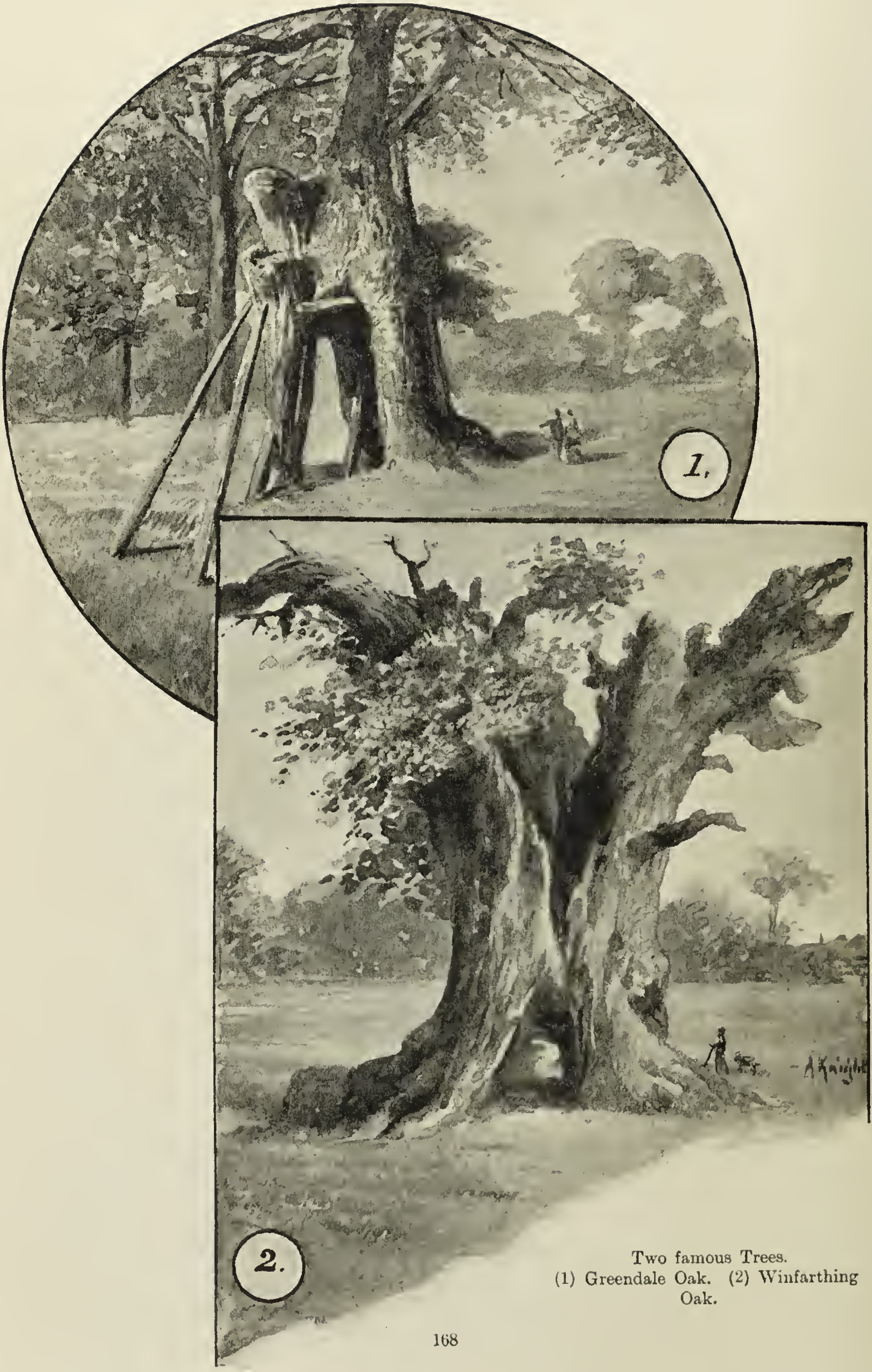
Fig. 188.—*Welwitschia mirabilis* from Little Fish Bay, South-West Tropical Africa.



Two famous Trees.
(1) Greendale Oak. (2) Winfarthing Oak.

CHAPTER VIII

LEAF-BEGINNINGS AND LEAF-FORMS

> "Only leaves? Yet where would any of us be to-day but for the silent offices of leaves?"—*Finger-post Essays.*

HAVING treated at some length in a previous chapter of the internal structure and functions of the leaves of plants, we may now devote a few pages to their external forms—a subject by no means easy to treat in a popular manner. Nevertheless, we think that it has recommendations of its own and will not be found unfruitful of interest.

The beginning of the leaf is the *bud.* The foliage buds which we see expanding in the spring are formed the autumn before; and the busy protoplasts, as though aware that the nipping frosts of winter will have to be faced by these nurslings of the Vegetable World, provide them with jackets which effectually keep out the cold, and which may be thrown off with the milder spring's return. These jackets are botanically known as *scale-leaves* or *bud-scales* (fig. 189).

In some plants—as the Horse-chestnut (*Æsculus Hippocastanum*)—the scales are covered with a gluey substance, resulting from the conversion into mucilage of a layer of epidermal cells beneath the cuticle, which increases their efficiency as bud protectors (see p. 170); while in many species of Willow (*Salix*) and not a few other plants the scales are provided with a coating of soft hair or down. When bud-scales are not developed, the leaf-like appendages—*stipules*—at the bases of the young leaves frequently serve as protectors, or the leaves themselves may be covered with wool. In the majority of cases—the Indiarubber-plant (*Ficus elastica*) may be cited as an example—these protective coverings drop off when the leaf is strong enough to bear exposure to sun and weather (fig. 191); but in others they persist throughout the life of the plant. The membranous stipules of the Tulip-tree (*Liriodendron tulipifera*) close

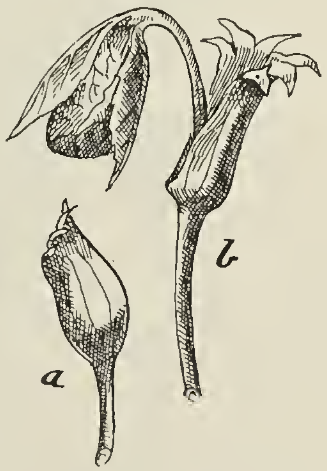
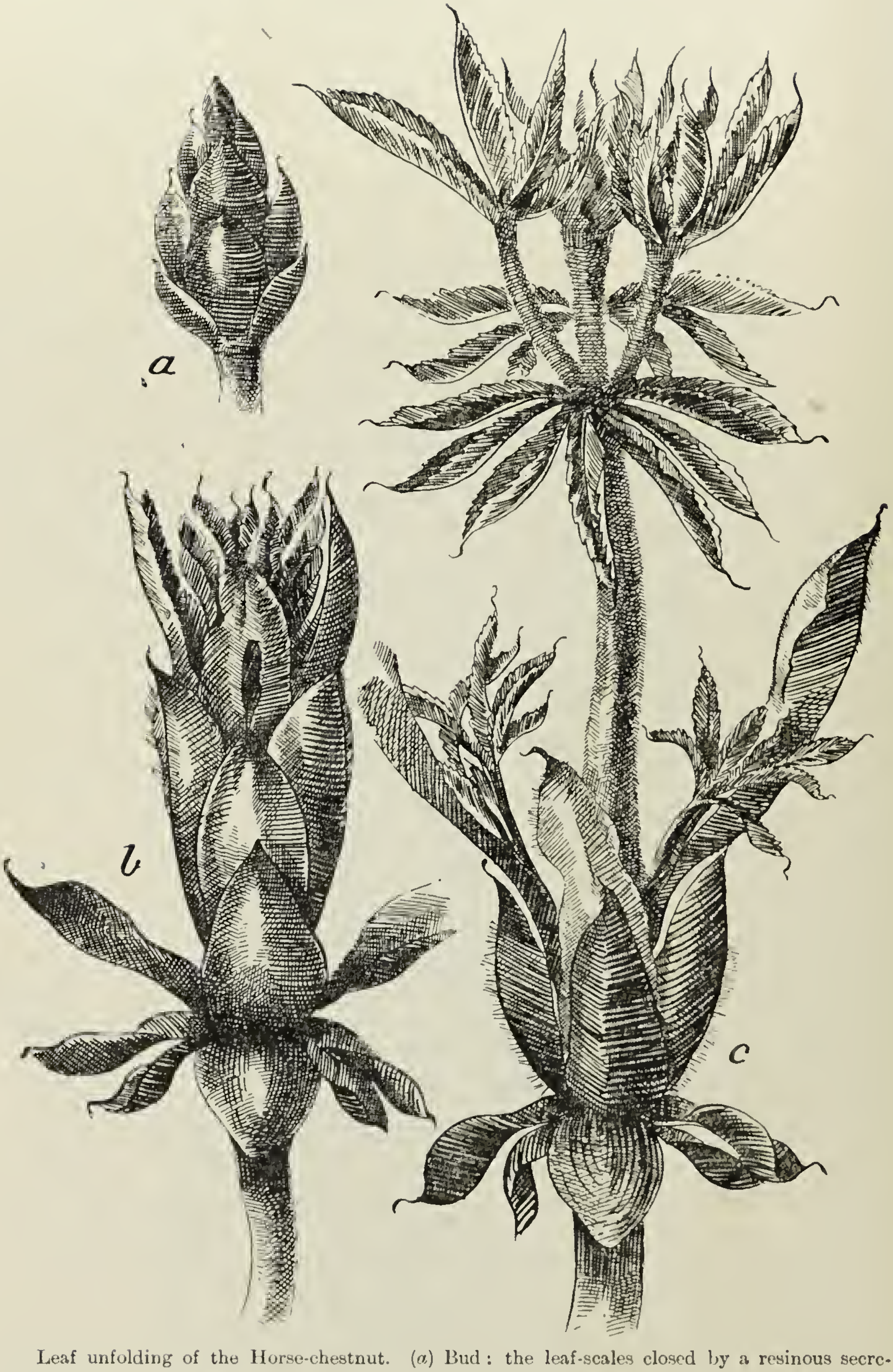


Fig. 189.—Bud-scale of Christmas Rose (*Helleborus niger*). (*a*) Closed. (*b*) Open, the young leaves emerging.



Leaf unfolding of the Horse-chestnut. (*a*) Bud: the leaf-scales closed by a resinous secretion. (*b*) Ditto: the leaf-scales bending back to liberate the leaves. (*c*) The same at a more advanced stage.

over the young leaf like the shells of a walnut; and on pulling them apart the folded leaf may be seen curled up, and looking as snug as a kitten in a basket (fig. 193). These stipules shrivel and fall off directly their work is done.

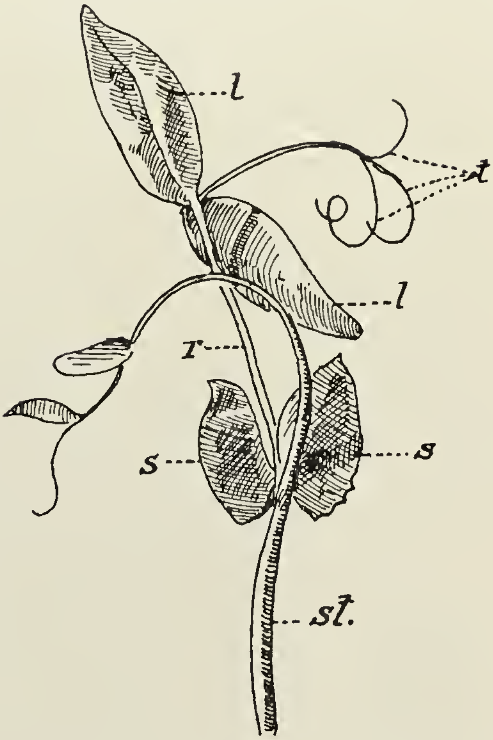


Fig. 190.—Branch of Sweet Pea (*Lathyrus odoratus*) with stipules (*s*), leaflets (*l*), and tendrils (*i.e.*, metamorphosed leaflets) (*t*). (*r*) Rachis. (*st*) Stem.

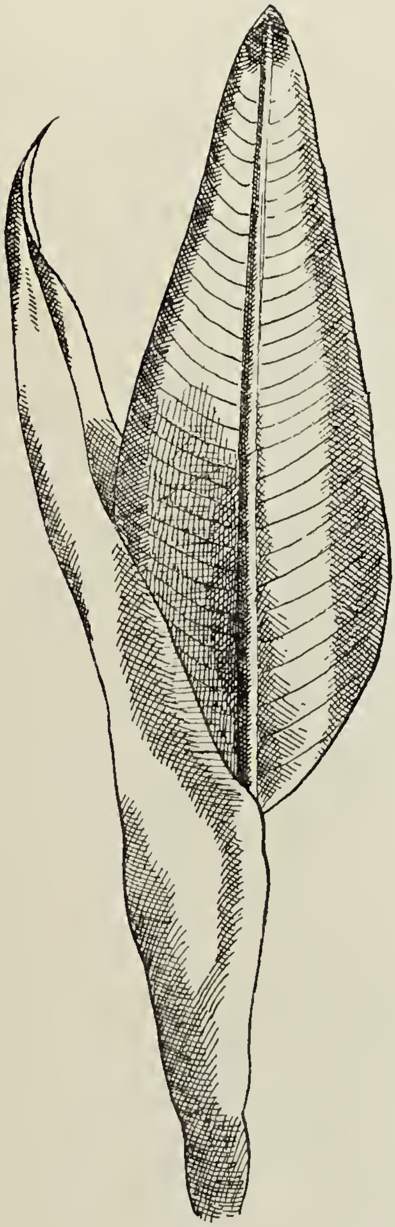


Fig. 191.—Leaf of the Indiarubber-plant throwing off its scale.

Another and more familiar form of protective bud-scales is the brown, dry, chaffy-looking growth which covers the tender green fronds of many Ferns, and which may be well studied in the Common Scale-fern (*Ceterach officinarum*), one of the prettiest of our mural species. The closely packed overlapping scales, which are of a rust-coloured brown, completely cover the under surface of the fronds; and in this case are persistent, for the plant grows in exposed situations and cannot afford to dispense with its chaffy under-vest as it grows older. When dry winds prevail or the sun is in his fiercer moods, the fronds roll up, and thus make the most of their protecting scales. The leaves of *evergreen* plants, which, though they have to brave the rigours of winter, lose their scales at an early period, are provided with a specially tough and water-tight epidermis, and their smooth glossy surfaces are admirably adapted to prevent the accumulation of snow upon them. Good examples are offered by the Common Holly (*Ilex Aquifolium*, fig. 196) and the Sweet Bay-tree (*Laurus nobilis*).

Buds are usually formed either at the ends of branches, when they are called *terminal*, or in the axils of leaves, when they are said to be *axillary*; and they are frequently found in both positions on the same plant. Those which fall under neither of these categories are described as *adventitious*. Adventitious buds apparently give rise to most of the leafy shoots on old tree-trunks;* and not infrequently they are developed on roots. Injury to the aerial parts of certain plants will induce the formation of *root-buds*. The felling of a tree, for example, may be the occasion for a whole crop of underground buds; for the protoplasts in the root may—and often *do*—recover from the shock, and being diverted from their regular work, they busy themselves in the formation of buds, from which, in due course, arise new leaf-shoots, containing all the promise and potency of future trunks.

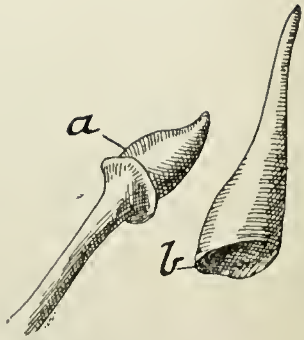


Fig. 192.—Bud protection in the Plane-tree (*Platanus orientalis*). (*a*) Bud. (*b*) Protecting cap.

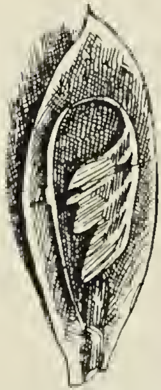


Fig. 193.—Young leaf of Tulip-tree lying in one of the stipules of the plant. The other stipule has been removed.

Occasionally adventitious buds are borne on leaves, and to such the name *epiphyllous* has been applied. If a leaf of one of the large-leaved species of *Begonia* or of *Gloxinia* be planted in a suitable soil, it will put out roots from its stalk, and buds from various parts of the blade—a fact of which horticulturists take every advantage. When it is desired to multiply any of these plants, the nurseryman collects a number of the older leaves, and having made incisions with a sharp knife across the

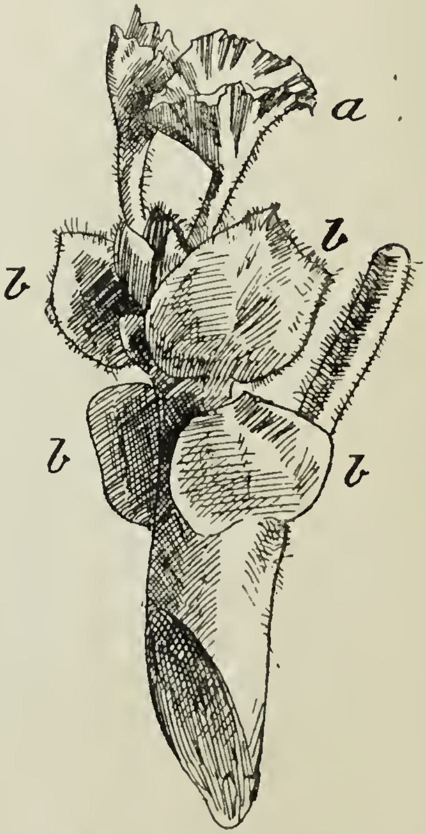


Fig. 194.—Leaf shoot of Scarlet Geranium (*Pelargonium inquinans*). (*a*) Young opening leaves. (*b*) Stipules.

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* Possibly, however, such buds are more often axillary buds which have lain dormant.

principal nerves on the under side, he spreads the leaves on sand or coconut fibre, and shades them carefully from the sun. As a result of this treatment, bulbils presently appear at the lower ends of the nerves, and when these have attained to a certain size, they are removed and placed in separate pots. Each bulbil is now a distinct plant.

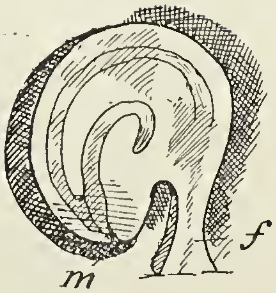

Fig. 195.—Campylotropous ovule of Pea. (*m*) Micropyle. (*f*) Funicle.

Epiphyllous buds are sometimes met with on Liliaceous and Orchideous plants, as well as on the Cuckoo-flower (*Cardamine pratensis*) and the Celandine (*Chelidonium majus*); but the plant which is most celebrated for its bud-bearing leaves is probably *Bryophyllum calycinum*, an Indian evergreen shrub of the House-leek family, common enough nowadays in English stovehouses, where it is grown as a curiosity. The thick fleshy leaves of this plant (fig. 197) need no artificial incisions to stimulate their productiveness. Nature has already notched the leaves at the margin, and every full-sized leaf, even when growing on the parent plant, exhibits at each of the notches a group of cells, the embryo bud, which to the naked eye appears like a speck. When one of these leaves is removed and placed in a moist situation, the buds develop and leafy shoots appear; while the old leaf soon falls to decay, and the young plants become independent and self-supporting.

A New Zealand Fern, *Asplenium bulbiferum*, is likewise noted for its budding propensities. The buds are borne on the divisions (*pinnules*) of the older fronds, which are so proliferous that a single plant may be the parent of many hundreds of new individuals (fig. 198). Other Ferns—as *Asplenium Edgeworthii*, *Ceratopteris thalictroides*, *Gleichenia cryptocarpa*, *G. flabellata*, and *G. Cunninghami*—display the same vital energy; indeed, there is reason for believing that a fern-frond is simply a cladode or flattened branch, and that the buds are normally produced like those of the cladodes

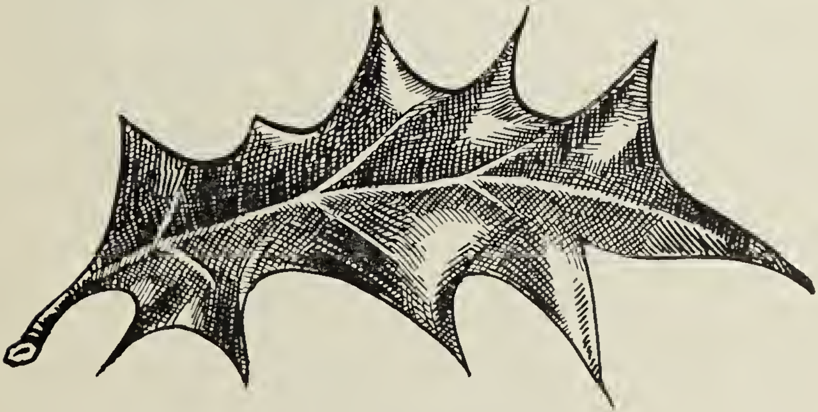

Fig. 196.—Leaf of Holly.

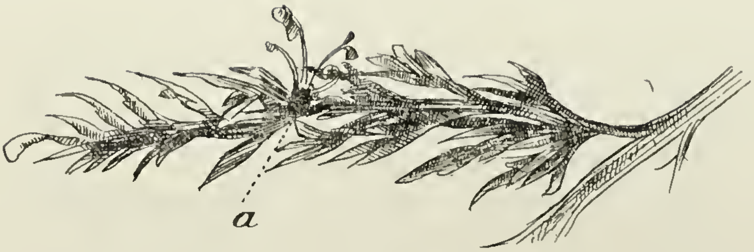

Fig. 198.—One of the pinnules of *Asplenium bulbiferum*. (*a*) A bud.

of the Butcher's Broom. A graceful North American species of Hart's-tongue Fern known as the Jumping-leaf (*Scolopendrium rhizophyllum*) usually produces buds at the ends of its narrow lance-shaped fronds. The fronds trail over until their slender tips touch the ground, when roots form on the under surface at the points of contact, and from the upper surface new fronds arise (fig. 199).

It may be well to remark here that the plant known as the Butcher's Broom Helwingia (*H. rusciflora*), the flower-buds of which are seated on the foliage-leaf, is not to be classed with plants like *Bryophyllum*, and for this reason: *the flower-buds of Helwingia are not true epiphyllous buds.* They do not spring from the *tissues* of the leaves on which they are seated, but from the *axes* of the leaves, and with these axes they are connected by strands, which are simply disguised flower-stalks. In short, the buds are not the result of protoplasmic activity in the leaf-tissue, but spring from the rudimentary flower-stalks, which differ from ordinary flower-stalks by being fused with the midrib of the leaf. Another plant which somewhat resembles Helwingia in this respect is *Phyllonoma ruscifolium*, a Mexican shrub; but the leaf in this case is surmounted by a long acumen (*a*), below the base of which the flowers appear (fig. 200).

The manner in which the young rudimentary leaves are arranged in the leaf-buds—in scientific parlance, their *vernation* or *prefoliation*—forms an interesting study. Each species of plant has its own particular method of folding its unexpanded leaves, and a definitive term is applied to each. In the Ferns (*Filices*) the fronds are coiled from tip to base (*circinnate*); in the Grasses (*Gramineæ*) from one side

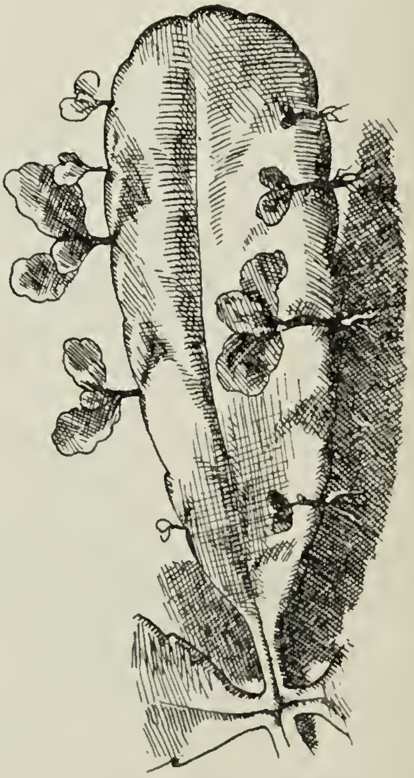

Fig. 197.—Formation of buds at the edges of a leaf of *Bryophyllum calycinum*.

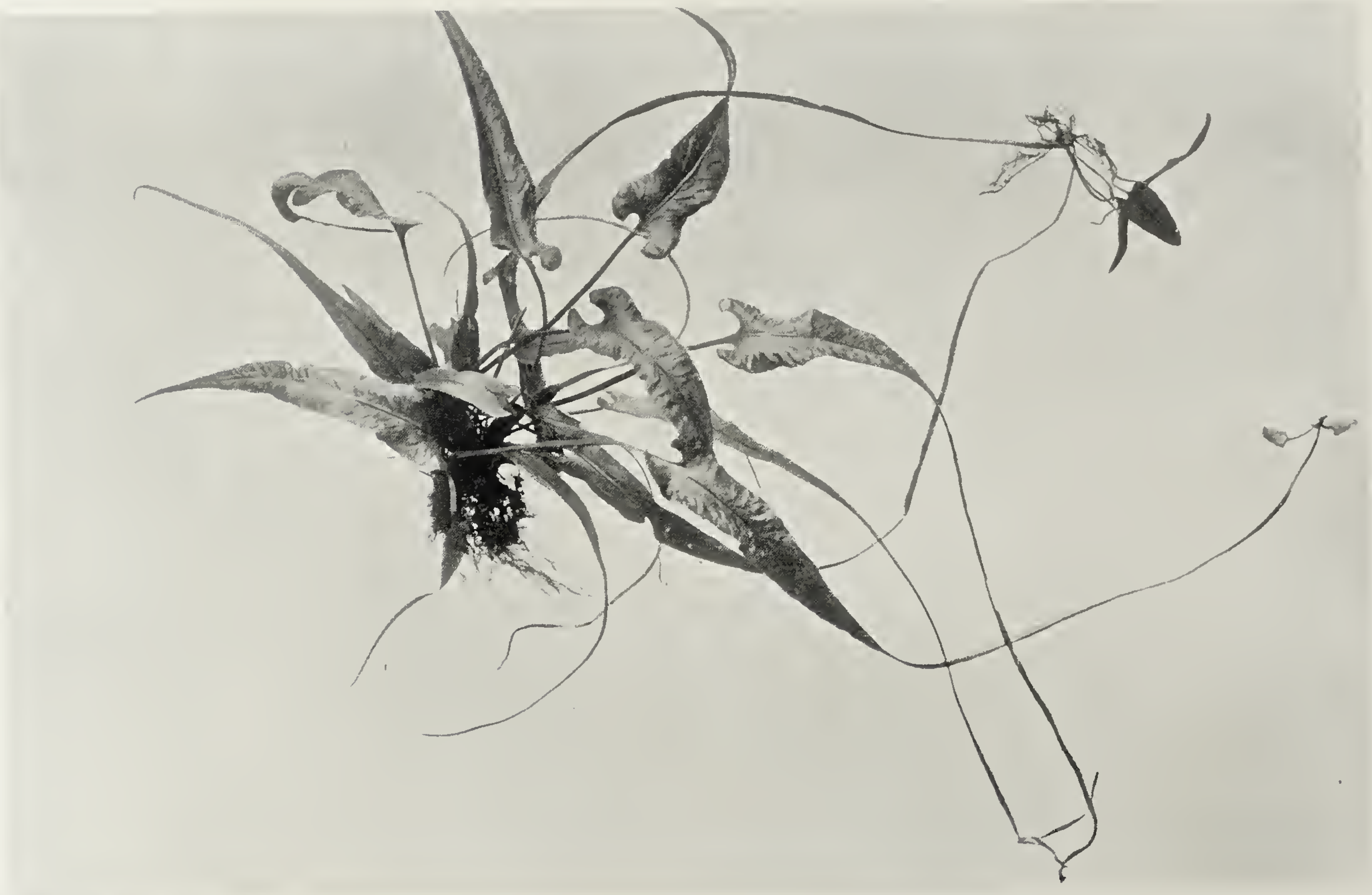

Photo by Henry Troth.

WALKING FERN (*Camptosorus rhizophyllus*—ALSO CALLED *Scolopendrium rhizophyllum*) WITH ROOTING FRONDS.

PLATE XIV.

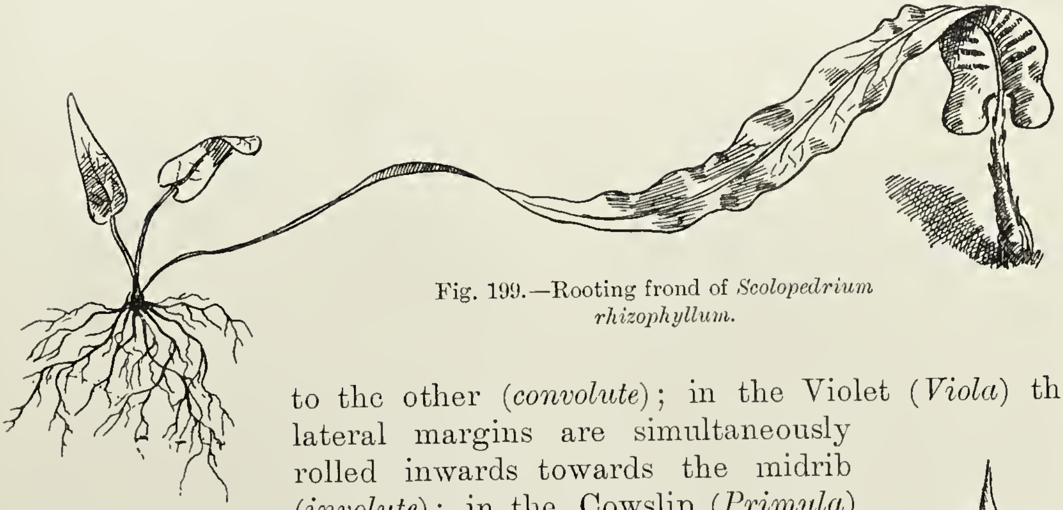

Fig. 199.—Rooting frond of *Scolopedrium rhizophyllum.*

to the other (*convolute*); in the Violet (*Viola*) the lateral margins are simultaneously rolled inwards towards the midrib (*involute*); in the Cowslip (*Primula*) and Dock (*Rumex*) a similar rolling is seen, but outwards (*revolute*); in the Currant (*Ribes*) and Beech (*Fagus*) the leaf is plaited with several folds lengthwise (*plicate*); and in the Cherry and Plum (*Prunus*) it is folded flat from the midrib with the edges in contact (*conduplicate*) (figs. 201-207). These distinguishing names being descriptive are easily acquired: but we do not lay stress upon them just now. The fact that we *would* emphasise (and it is *very* remarkable) is this—that the tissues forming the leaves are manufactured *folded up*! We can understand a loom weaving a material, and *then* folding it; but here is the material folded up, and unfolding only when it is all woven!

The arrangement of the mature and developed leaves on the stem is also worthy of attention. To regard the mass of foliage on a tree as an orderly arranged series of organs might seem to be a far-fetched thought; yet order reigns in Nature where the unpractised eye sees only disorder. It was long ago remarked by Charles Bonnet, an eminent Swiss naturalist of the eighteenth century, that leaves and their modifications have normally a spiral arrangement on the stem. The fact (for the truth of the observation is beyond question) is more easily understood of the foliar than of the floral leaves, and may be better seen in some plants than in others. It is spoken of as phyllotaxy.

The leaves of a Cherry-tree (*Cerasus*) will furnish a suitable illustration. Here (fig. 208) is a piece of a branch with all the leaves belonging to it. We will number them in their order of growth, 1, 2, 3, 4, 5, and 6. Now

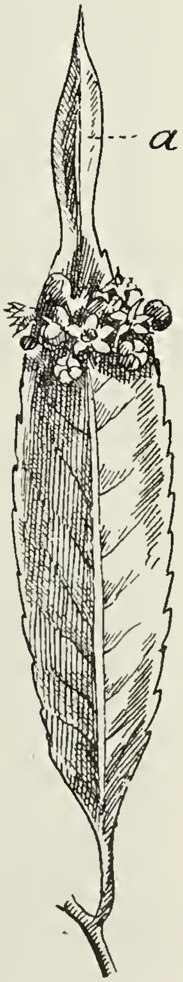

Fig. 200.—Flowering branch of *Phyllonoma ruscifolium.* (*a*) Acumen.

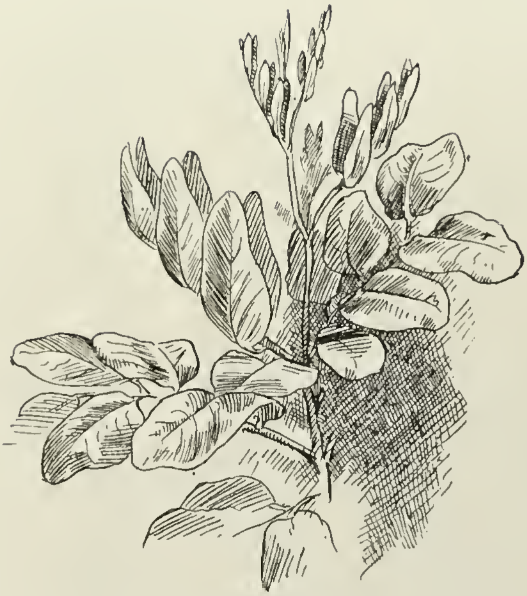
Fig. 201.—Leaf unfolding of the Carob-tree (*Ceratonia Siliqua*).

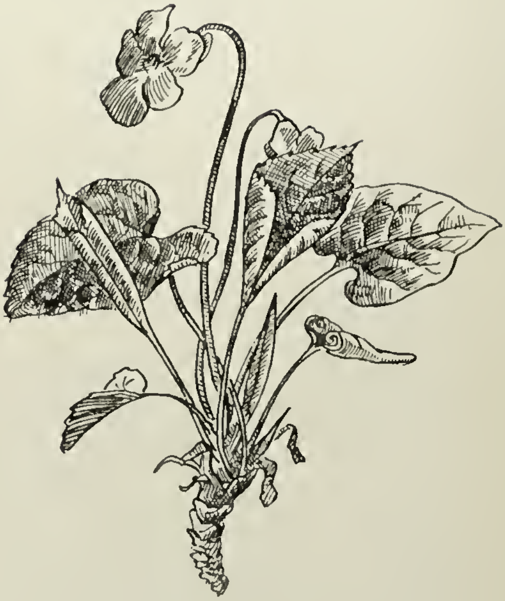
Fig. 202.—Involute vernation of Sweet Violet (*Viola odorata*).

for our spiral. Commencing at number 1, draw a chalk line from the base of the leaf to the base of number 2, and from thence to the same point in leaf 3, and so on, to the base of each leaf in succession till number 6 is reached. See now what has happened! The chalk line has traversed in a spiral manner exactly twice round the branch, and the beginning of the line at number 1 is exactly under the end of the line at

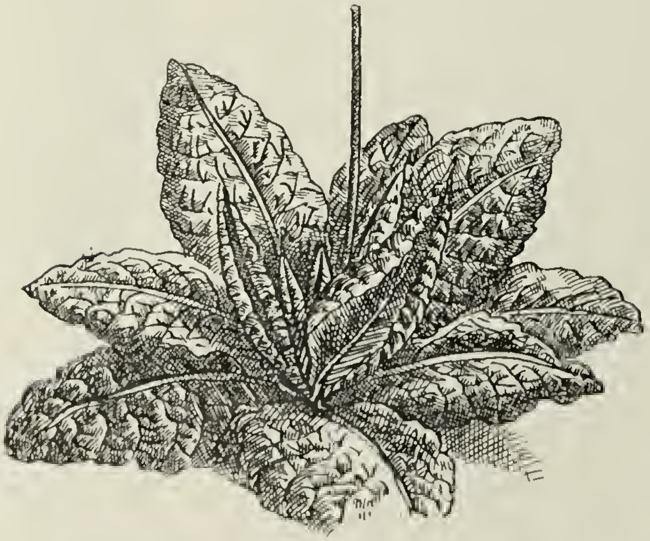
Fig. 203.—Revolute vernation of Oxlip (*Primula elatior*).

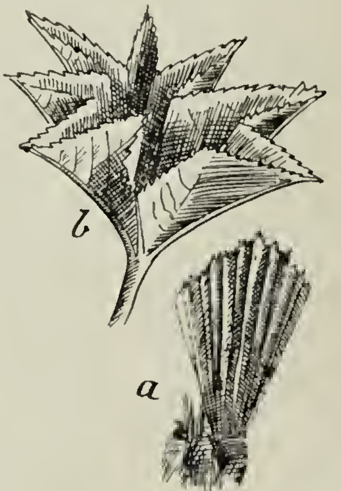

Fig. 204.—Plaited vernation of Lady's Mantle (*Alchemilla*). (*a*) Leaf at an early stage. (*b*) Later stage of same leaf.

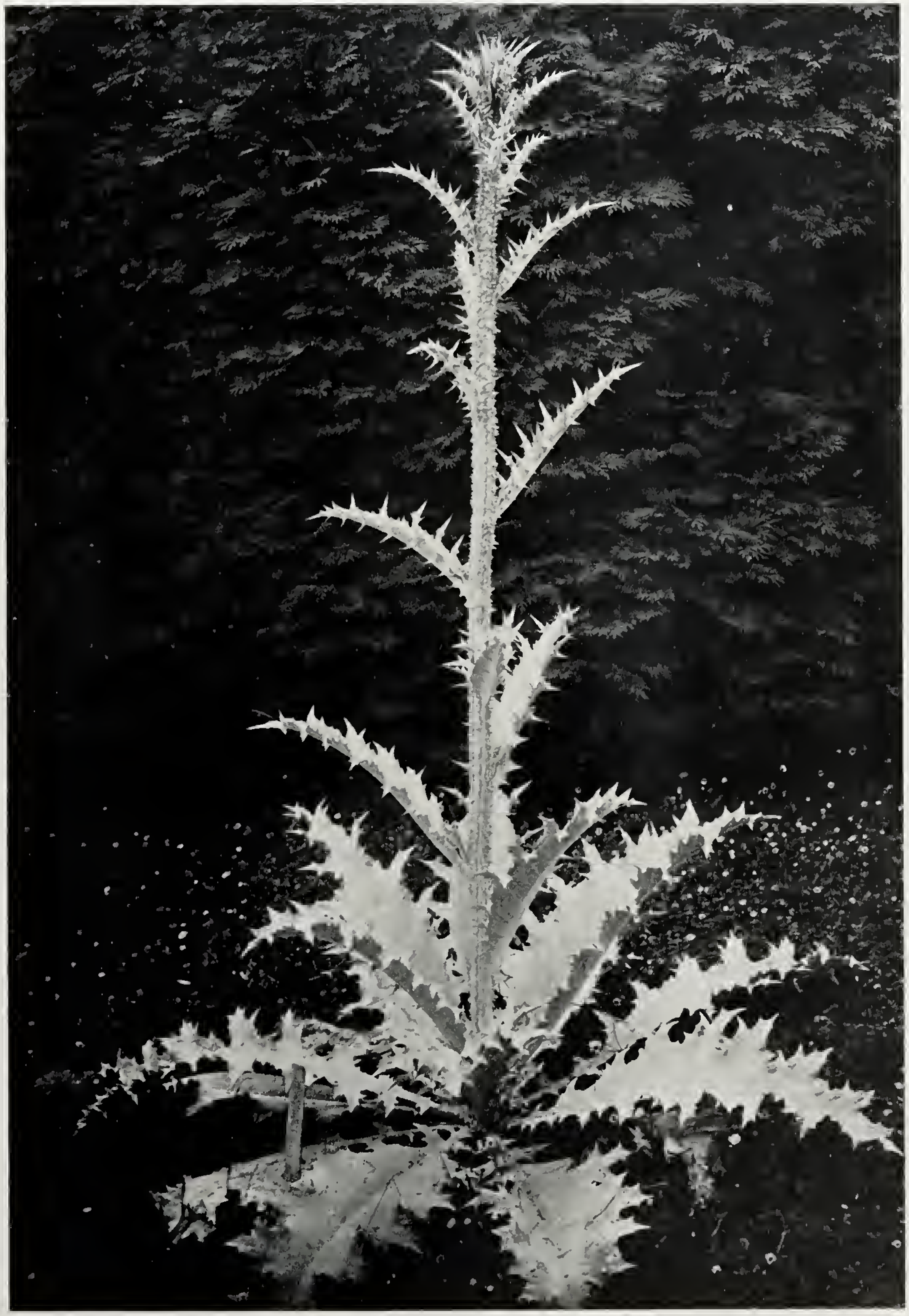

Photo by W. Rossiter.

One of the Cotton Thistles (*Onopordon bracteatum*).

Grown at Bath, where it flowered for the first time in this country. The spiral arrangement of the leaves on the stem is very clearly marked in the illustration.

Plate IX.

number 6; or, in other words, the first leaf corresponds vertically with the sixth. Had the fragment of branch been longer, and contained eleven leaves instead of six, we should have found on continuing the line in the same manner—that is, from base to base of the additional leaves—that the point of the chalk would have travelled, as before, twice round the branch in order to reach number 11. Moreover, and as a consequence, the leaf specified would have been found to be in the same vertical line as 1 and 6. As to the other leaves, number 7 would have been found to be over number 2, 8 over 3, 9 over 4, and 10 over 5—in fact, the interesting discovery would have been reached that the leaves are disposed on the branches in *cycles* of five; and way would have been cleared for the statement that the laws which regulate the foliar arrangement of all plants, and the floral no less than the foliar, may be reduced to the same mathematical precision (fig. 209).

Not, of course, that the leaves of all plants fall under the same arrangement as the Cherry. In monocotyledons—particularly the Grasses—the arrangement is often two-ranked (*distichous*); that is to say, the third leaf is over the first, the fifth over the third, etc.; while on the opposite side of the stem the fourth leaf is over the second, the sixth over the fourth, and so on. A three-ranked (*tristichous*) arrangement is, however, by far the most common among monocotyledons. The cycles in such instances are three-leaved, numbers 4, 7, 10, 13, etc., each commencing a new cycle. An eight-ranked (*octastichous*) arrangement (eight leaves in a cycle) is found in the Holly (*Ilex*), Aconite, and many other plants. The above are, perhaps, the most common varieties of *phyllotaxis*, but

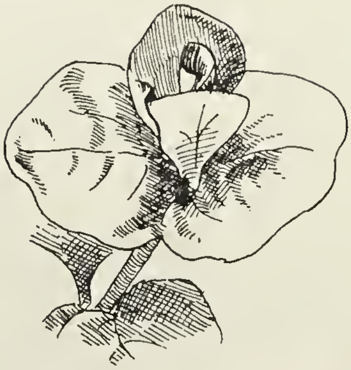

Fig. 205.—Convolute leaf unfolding of Periwinkle (*Vinca*).

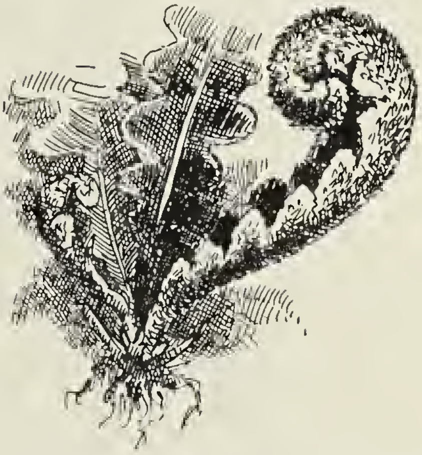

Fig. 206.—Young frond of Common Scale Fern (*Ceterach officinarum*).

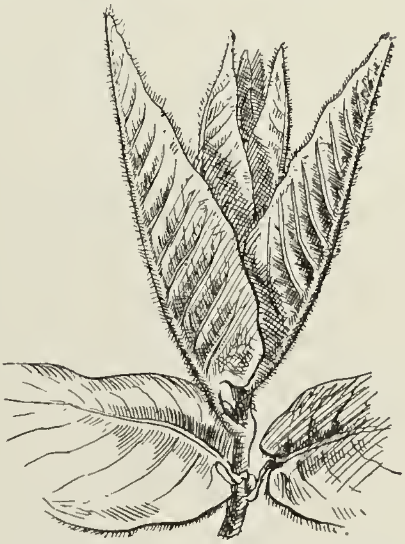

Fig. 207.—Conduplicate vernation of *Castilloa elastica* (from which caoutchouc is obtained).

the list is very far from exhausted when these have been enumerated. A Fir-cone is simply a collection of modified leaves, arranged in a highly characteristic spiral manner.

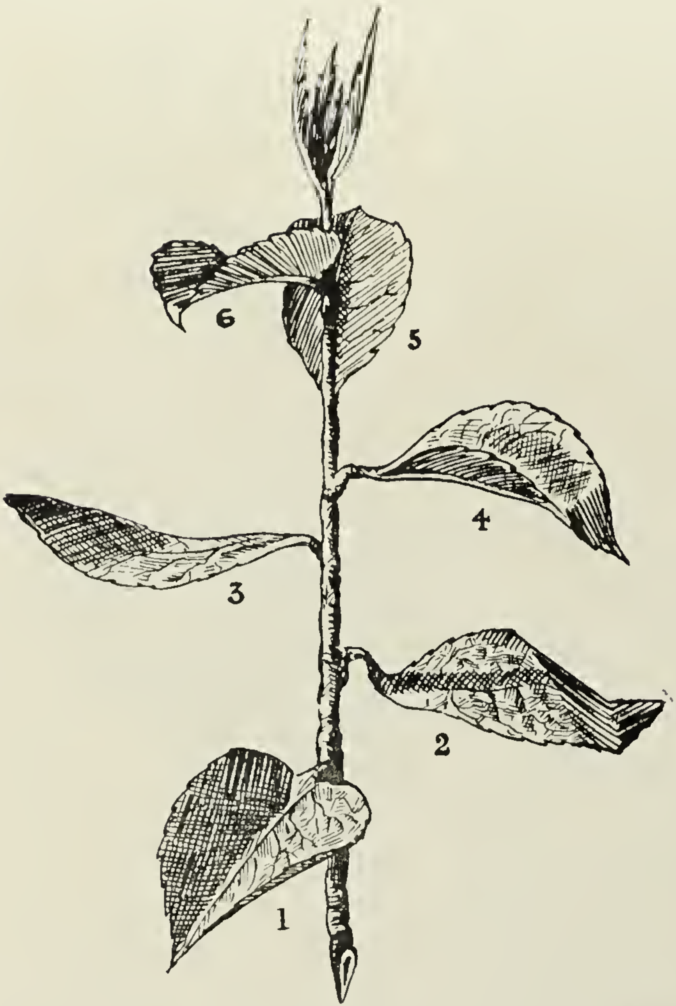

Fig. 208.—Five-ranked (pentastichous) arrangement of leaves of the Cherry.

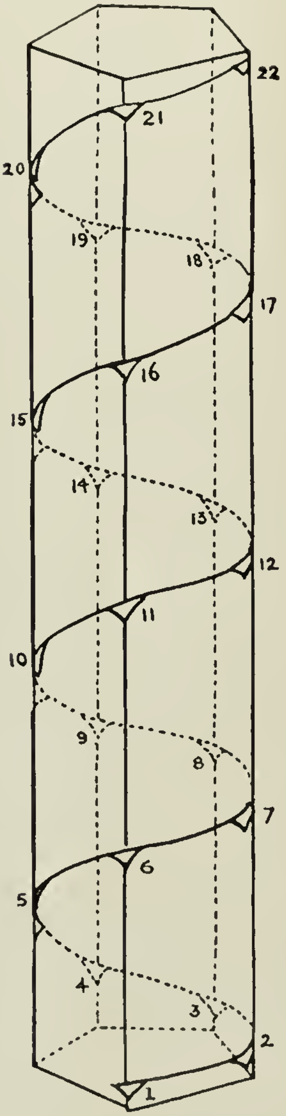

Fig. 209.—Diagram of a stem with scars of twenty-two leaves arranged in a five-ranked (pentastichous) manner.

All plants, we must remember, do not possess leaves. The Broomrapes and Dodders, for example—those thriftless parasites which feed upon the juices elaborated by the host plants to which they attach themselves—have no need of leaves. The *Cacti* and many tropical Euphorbias are also deficient in these organs, though their spines are really metamorphosed leaves or branches, affording them (as we saw on a former occasion) protection from herbivorous wild animals. Leafless plants, however, are exceptional among Phanerogams, and it is only when we descend the scale of Vegetable Life, and place ourselves among

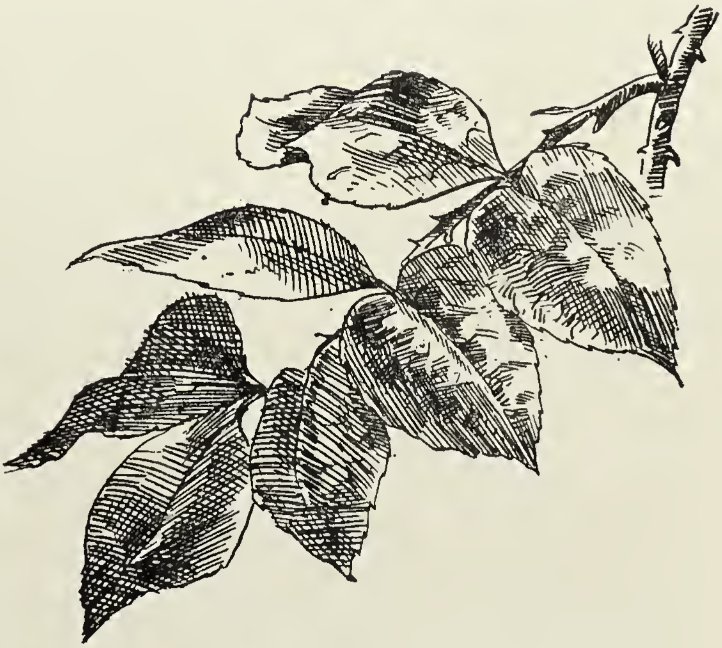

Fig. 211.—Compound leaf of a dicotyledonous plant.

the Cryptogams, or Flowerless Plants, that a general absence of leaves becomes apparent. The Ferns have them, it is true, their green *fronds* being among the chief beauties of Nature. The Mosses have them also, but their minute and delicate leaves are destitute both of woody vessels and stomata, and can scarcely be ranked with the busy sap-elaborating organs of Flowering Plants. The Fungi are provided with nothing analogous to leaves; nor is any provision necessary, as the food on which they thrive is derived from a host (plant or animal) or from decomposed organic matter which does not need to be elaborated by exposure to light and air.

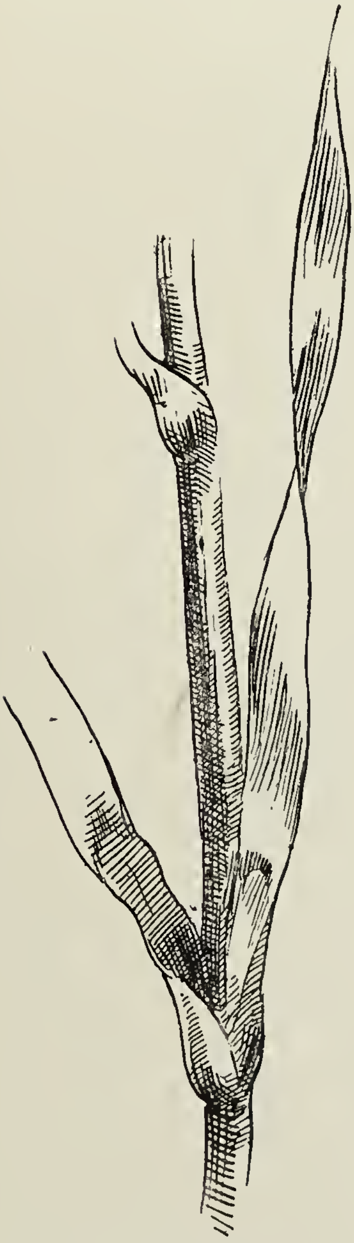

Fig. 210.—Grass stem and leaves.

A systematic description of the various forms of leaves would, we fear, be very wearisome. The names themselves are as numerous as the names of the English sovereigns from Egbert to Victoria, and by no means as easy to remember. Not only has every part of a typical leaf its Latin appellation, but every sort of margin, base, and apex has a qualifying cognomen. In a Grass-leaf, for example (fig. 210), the flattened upper part of the leaf is called the *blade*; the portion enfolding the stem is the *sheath*; and the scale-like formation between the sheath and blade is the *ligule*. Moreover, the leaf is *parallel-veined—i.e.*, the fibrous bundles which form the skeleton run side by side without interlacing—a characteristic feature of almost all monocotyledons;* its margin is *entire—i.e.*, it is even and smooth all round, and its shape is *linear*.

The parts of a dicotyledonous leaf have an even greater number of distinguishing names. Take, for instance, the *compound* leaf of the Dog-rose (*Rosa canina*, fig. 211). The leaf as a whole is called compound because its stalk bears numerous leaflets: it is *pinnate* (Lat. *pinnatus*, feathered) because these leaflets grow featherwise along the sides of the stalk, and it is unequally or *impari-pinnate* because there is an odd lobe at the extremity.† The leaflets themselves are *net-veined*, the large central vein in each being known as the *midrib*; their shapes are *broadly elliptical*, and their sharp, saw-like margins are *serrate* (Lat. *serratus*, saw-like). The portion of the leaf-stalk at the base of the leaf is the *petiole* (Lat. *petiolus*, a little foot); but beyond the first pair of leaflets it is called the *rachis* (Greek *rachis*, the spine). The two small leaf-like organs at the base of the petiole are *stipules* (Lat. *stipula*, a blade).

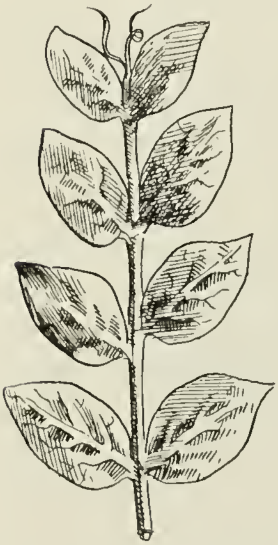

Fig. 212.—Paripinnate leaf of Seaside Everlasting Pea (*Lathyrus maritimus*).

Now all this is very bewildering; nevertheless, a few walks in the country, if the neighbourhood be at all favourable for botanising, will soon familiarise one with the principal leaf-forms, and more will probably be learnt in a single hour thus spent (with text-book in hand for reference) than in five or six hours of wearying desk-work. There is a spot which we could mention, not twenty miles from London, which is peculiarly adapted for this purpose. It is a charming piece of Surrey landscape, in his lifetime a favourite spot with that prince of Nature-interpreters, Richard Jefferies; so we will transport ourselves thither in imagination, and saunter together down the shady lane, not yet disfigured by lamp-post or flaming letter-box, and beside a narrow stream which separates the parson's few acres

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* There are three or four British monocotyledons—notably the Black Bryony (*Tamus communis*) and the Cuckoo-pint (*Arum maculatum*)—which have net-veined leaves.

† Compound leaves which have no such terminal lobe, but all the leaflets of which run in pairs (fig. 212), are described as *pari-pinnate* (Lat. *par*, *paris*, equal, and *pinnatus*). We get this form in the Vetches (*Vicia*). In many of the Acacias each of the *pinnæ* of the pinnate leaves is itself pinnate, so that the form is doubly or *bi-pinnate* (fig. 213); while in the Lesser Meadow-rue (*Thalictrum minus*) the division is carried a step further, and we have a *tri-pinnate* form (fig. 214).

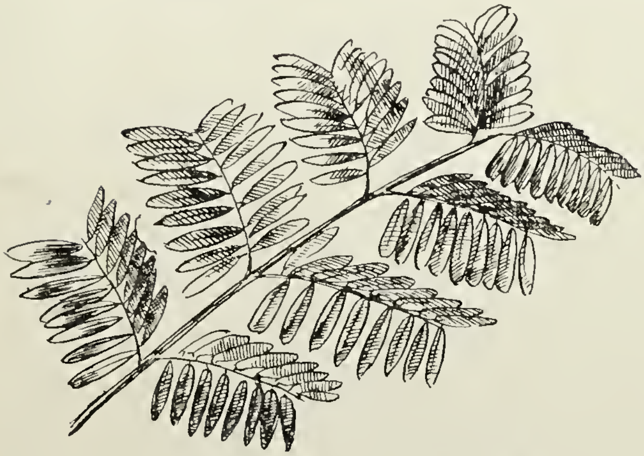


Fig. 213.—Bipinnate leaf of *Acacia arabica.*

from the neighbouring farm, and so on to the schoolmaster's cottage, gathering our leaves by the way. Lane, stream, meadow, cornfield, cottage garden—these will supply all, and more than all, the forms required, and future rambles will help to fix in the memory the facts elicited.

Behold, then, the lane!—winding, odorous, leafy; a spot for poesy, such as might rouse the happy muse in a Clare or Cowper, or move to loving activity the pencil of a Birket Foster. It is a bright June day, and the song of birds, the hum of innumerable flying insects, and the click of the grasshopper make music the whole way along. Noble Chestnut-trees (*Æsculus Hippocastanum*) rise out of the lane-side hedges at every few paces, and their branches meet over us, their spreading *digitate* leaves affording welcome shade (fig. 215). An ivy-clad Oak (*Quercus Robur*) is also passed, easily to be recognised by its knotty, widespread branches and wealth of *sinuate* leaves (fig. 216). Shakespeare, whose quick eye let nothing escape him, called this tree "the unwedgeable and gnarlèd Oak," and no description could be more appropriate. Notice the Ivy. It is the common Ivy (*Hedera Helix*), a familiar object everywhere (fig. 217, *a*). The beauty of its light-veined leaves has often been celebrated by poets. Observe particularly the direction of the principal veins in one of these leaves. They radiate outwards from the base of the leaf, like the outspread fingers of the hand; and hence are called *palmately veined.* The leaves on the climbing stems of the Ivy are always lobed, and the depressions or sinuses between the lobes are usually shallow; but in other leaves—as the common Ragwort (*Senecio Jacobæa*)—they are deep and pinnate (fig. 217, *b*). That bushy-looking weed, whose pale green purple-tipped flowers must be sought for earlier in the year, is the Stinking Hellebore (*Helleborus fœtidus*); and we are fortu-

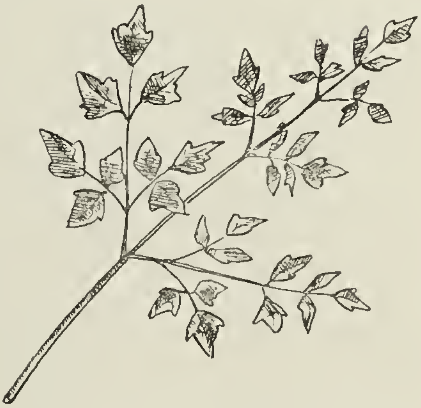


Fig. 214.—Tripinnate leaf of Lesser Meadow-rue (*Thalictrum minus*).

The Lane.

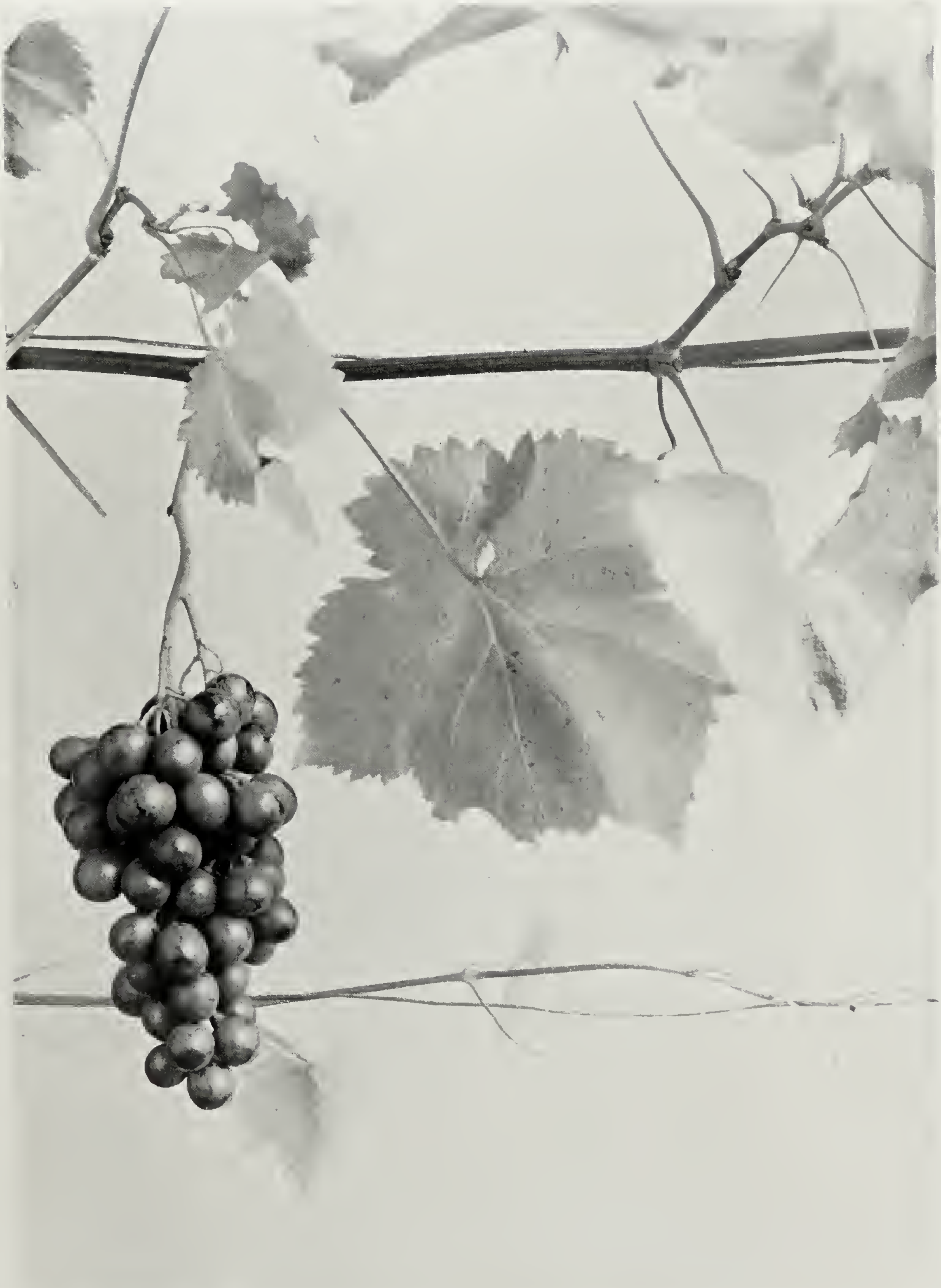


Photo by Henry Irving.

FRUITING BRANCH OF THE GRAPE VINE (*Vitis vinifera*), WITH LOBED AND SINUATE TOOTHED LEAVES.
PLATE XV.

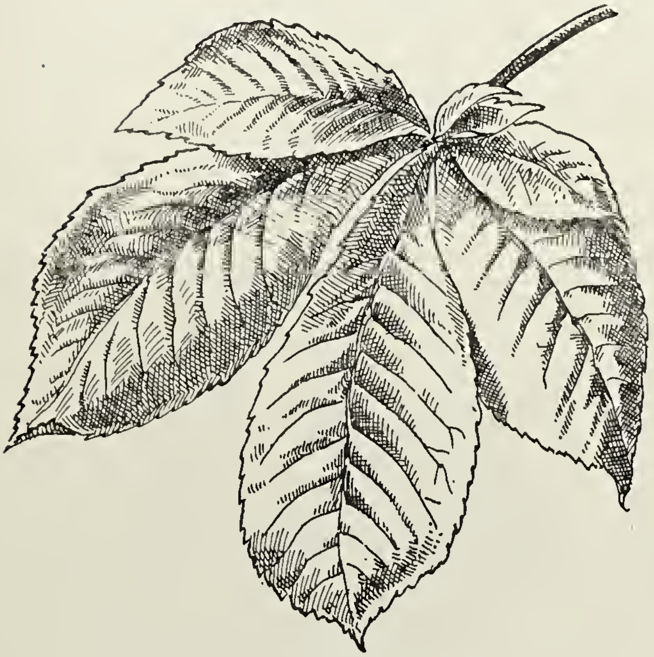


Fig. 215.—Digitate leaf of Horse-chestnut.

nate in meeting with a specimen here, as the plant is rarely found growing wild. Its palmately veined leaves are deeply divided, on which account they are called *palmatipartite* (fig. 218); while the downward-turned lobes at the base of each define their place as among *pedate* leaves. Palmatipartite leaves should be carefully distinguished, on the one hand, from palmately lobed (*palmatifid*) leaves, the divisions of which do not extend so far as those of the former; and, on the other hand, from palmately cleft (*palmatisect*) leaves, in which the divisions extend very nearly to the base. The branch of Ivy which we were just examining offers examples of palmatifid leaves, and the well-known Monkshood (*Aconitum Napellus*), of which the schoolmaster's garden will furnish specimens, bears leaves of the deeply cut palmatisect form (fig. 219, *a*).

As we are now down among the grass, we may pause a moment to admire the slender white blossoms and pretty leaves of the little Trefoil, creeping in and out between the cool blades. It is a species of Clover or Trefoil (*Trifolium subterraneum*, fig. 219, *b*). Notice that the tiny leaflets all spring from the top of the *petiole* or leaf-stalk, just as in the case of the Horse-chestnut-leaf gathered at the beginning of our walk; and as these leaflets are always three in number in the Trefoil, its leaves are said to be 3-foliate

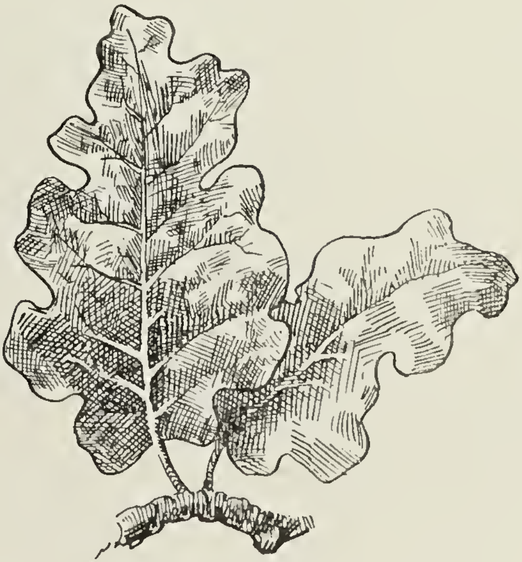


Fig. 216.—Sinuate leaves of Oak.

or *ternate*. We say "*always* three in number," but now and again a sprig with only two leaflets will turn up, and if the happy finder of this *rarum folium* be an East-country maiden, she will probably treasure it as a charm.

A Clover, a Clover of two,
Put it on your right shoe;
The first young man you meet,
In meadow, lane, or street,
You'll have him, or one of his name.

So runs the rhyme; while the finding of a 4-foliate Clover-leaf is said to be a hardly less auspicious event:—

If you find an even Ash-leaf or a
four-leaved Clover,
Look to meet your true love ere the
day be over.

But two- and four-leaved Clovers must be regarded as abnormal occurrences, the 3-foliate form being sufficiently common to be characteristic; and hence the Latin name of the genus, *Trifolium*, is quite appropriate. Horse-chestnut-leaves, on the other hand, regularly vary as to the number of their leaflets, and you will often find on the same tree 5-foliate or *quinate* forms, 7-foliate or *septenate*, and so on. When a ternate leaf is further subdivided, it becomes either *biternate* or *triternate*, as in the Masterwort (*Peucedanum Ostruthium*) and Baneberry (*Actæa spicata*) respectively. The Herb-paris (*Paris quadrifolia*), which should be looked for in moist and shady woods, has, as its Latin name implies, 4-foliate (*quadrate*) leaves.

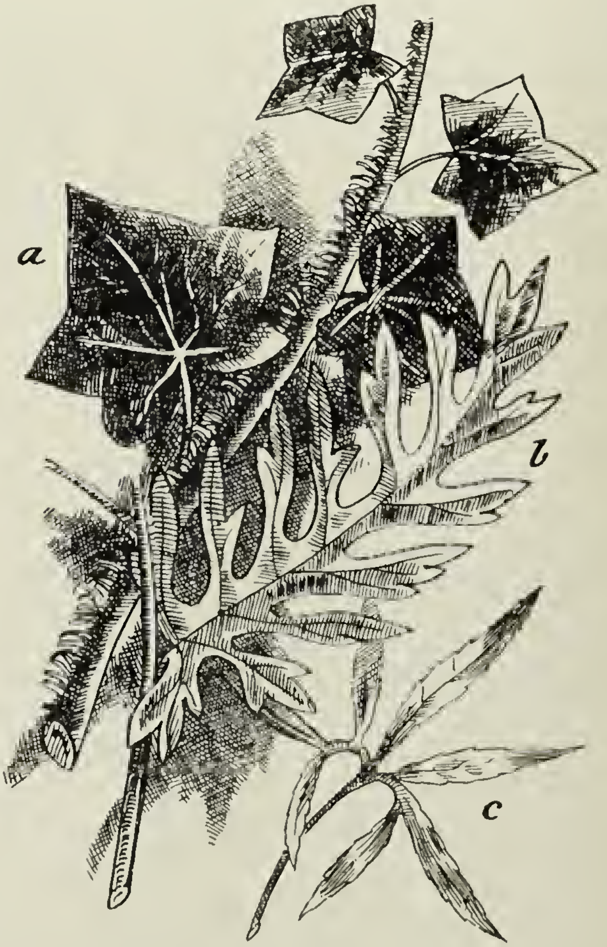


Fig. 217.—(*a*) Palmate and palmatifid leaves of Ivy with shallow sinuses. (*b*) Pinnate leaf of Ragwort with deep sinuses. (*c*) Palmatipartite and pedate leaf of *Helleborus*.

Let us linger among these meadow Grasses a moment longer while we examine a single blade of one of them, with Ruskin for our guide and teacher. "Nothing there, as it seems, of notable goodness and beauty," he says to us. "A very little strength and a very little tallness, and a

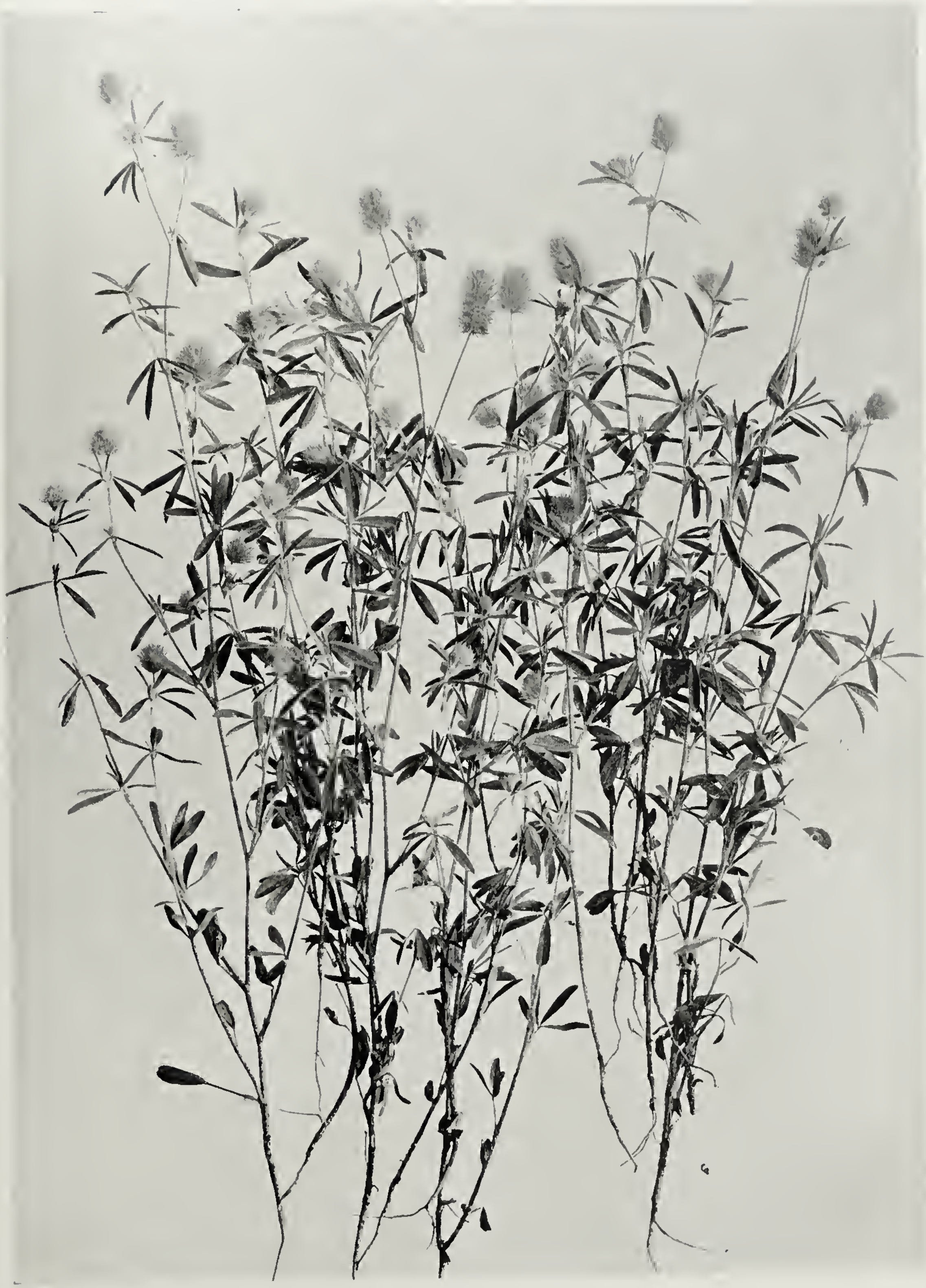


Photo by Henry Troth.

Hare's-foot Clover (*Trifolium arvense.*)

One of the British species of Clover, with trifoliolate leaves.

Plate XIII.

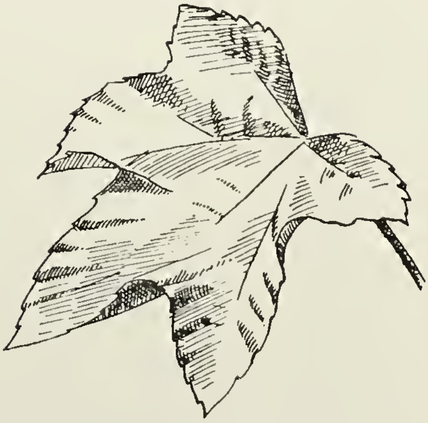


Fig. 218.—Palmate-veined leaf of *Malva sylvestris.*

few delicate long lines meeting in a point—not a perfect point neither, but blunt and unfinished, by no means a creditable or apparently much-cared-for example of Nature's workmanship, made only to be trodden on to-day, and to-morrow to be cast into the oven—and a little pale and hollow stalk, feeble and flaccid, leading down to the dull brown fibres of roots. And yet, think of it well, and judge whether, of all the gorgeous flowers that beam in summer air, and of all strong and goodly trees, pleasant to the eyes, or good for food—stately Palm and Pine, strong Ash and Oak, scented Citron, burdened Vine—there be any by man so deeply loved, by God so highly graced, as that narrow point of feeble green." The specimen we have gathered is the Sweet-scented Vernal-grass (*Anthoxanthum odoratum*), a Grass to which our summer hayfields owe much of their fragrance. The scent is a volatile oil contained in minute glands in the husk-like valves or glumes of the flowers (fig. 220).

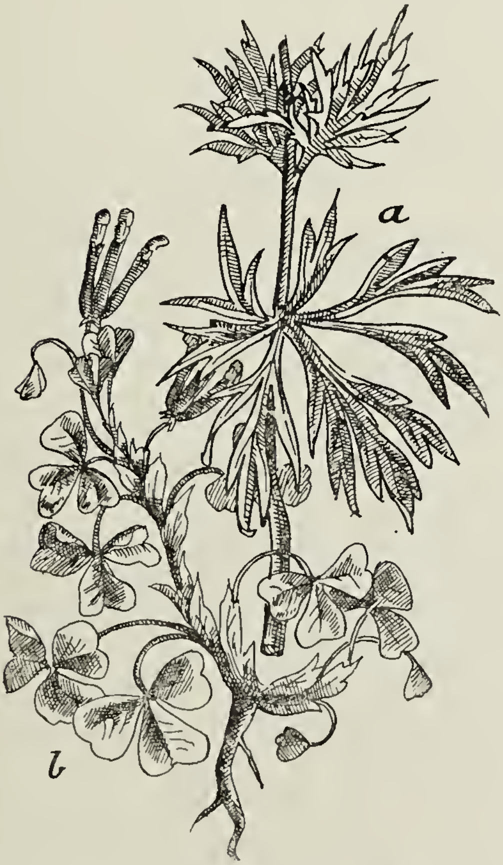


Fig. 219.—(*a*) Palmatisect leaves of Monkshood. (*b*) Ternate leaves of *Trifolium subterraneum.*

But we are now at the end of the lane, and fields, farm, and stream are all in view. On pushing open the crazy swing-gate, the first weed to greet our gaze is the Yellow Star-thistle (*Centaurea solstitialis*), whose flower-head, surrounded by a collar of needle-like spines, is just preparing to open. Mark the absence of petioles on its leaves, which are therefore called *sessile* (fig. 221, *a*). In another week the yellow florets will be open, and you will find in their delicate structures much that will repay attention. A three-fold pocket lense, which no field botanist should be without, will reveal a world of beauty in this simple weed. Yonder, not five paces off, is a cluster of the Common Buttercup (*Ranunculus*), with its golden cup—the "winking Mary-buds" of Shakespeare. Here, instead of the absence of leaf-stalks, you have petioles of an unusual length (fig. 221, *b*). Observe how they clasp the stems with their expanded bases. We name such leaves *amplexicaul*, or stem-clasping.

And now step a little nearer to the stream that skirts the meadow, and regard carefully the tall plant which lifts its purple crest by the water's edge. It is a Marsh Plume-thistle (*Cnicus palustris*). Its brown tinged thorny leaves recall old Chaucer's lines:—

> For thistles sharp of many maners,
> Netlis, thornes, and crooked briers;
> For moche they distroubled me,
> For sore I dredid to harmèd be.

Notice that the lower part of the leaf is united for a certain length with the stem, which is on that account called *winged*. The leaf is *decurrent* (fig. 221, *c*).

As we are now so close to the hedge, peep through the gap into the cornfield beyond, and observe that singular plant with small greenish yellow flowers, whose stem, branched at the top, passes almost through the centre of the oval leaves (fig. 222, *b*). It is the Common Hare's-ear (*Bupleurum rotundifolium*). Our Saxon forefathers called it Thorow-wax, from the circumstance of the stalk going through (A.S. *thorow*) the leaf; *wax* being the old word for "grow." Our Latin-loving botanists of to-day call such leaves *perfoliate*. Ah! you have smelt the Honeysuckle. Had you waited another week you would have been too late, for this is the rare Perfoliate Honeysuckle (*Lonicera Caprifolium*), which seldom flowers after June and which is almost confined to Oxfordshire and Cambridgeshire. There it is, twining in and out among the Privet bushes. Observe its sessile upper leaves (fig. 222, *a*), which look as if they have grown together at their bases. Leaves which offer this singular appearance are described as *connate*. More familiar examples may be found in the Yellow Wort (*Chlora perfoliata*) and the Teasel (*Dipsacus sylvestris*).

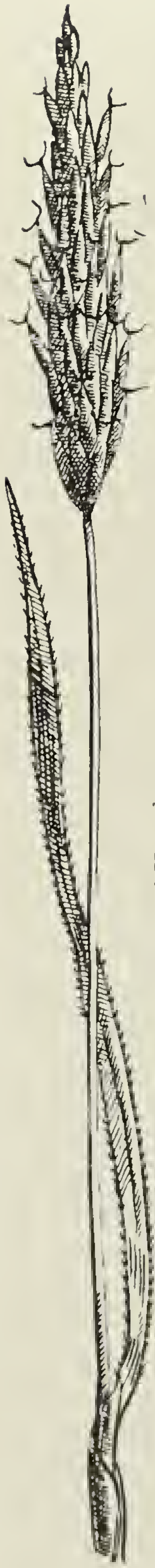


Fig. 220.—Spike and leaf of Sweet-scented Vernal-grass.

Before moving away you should notice the lanc-

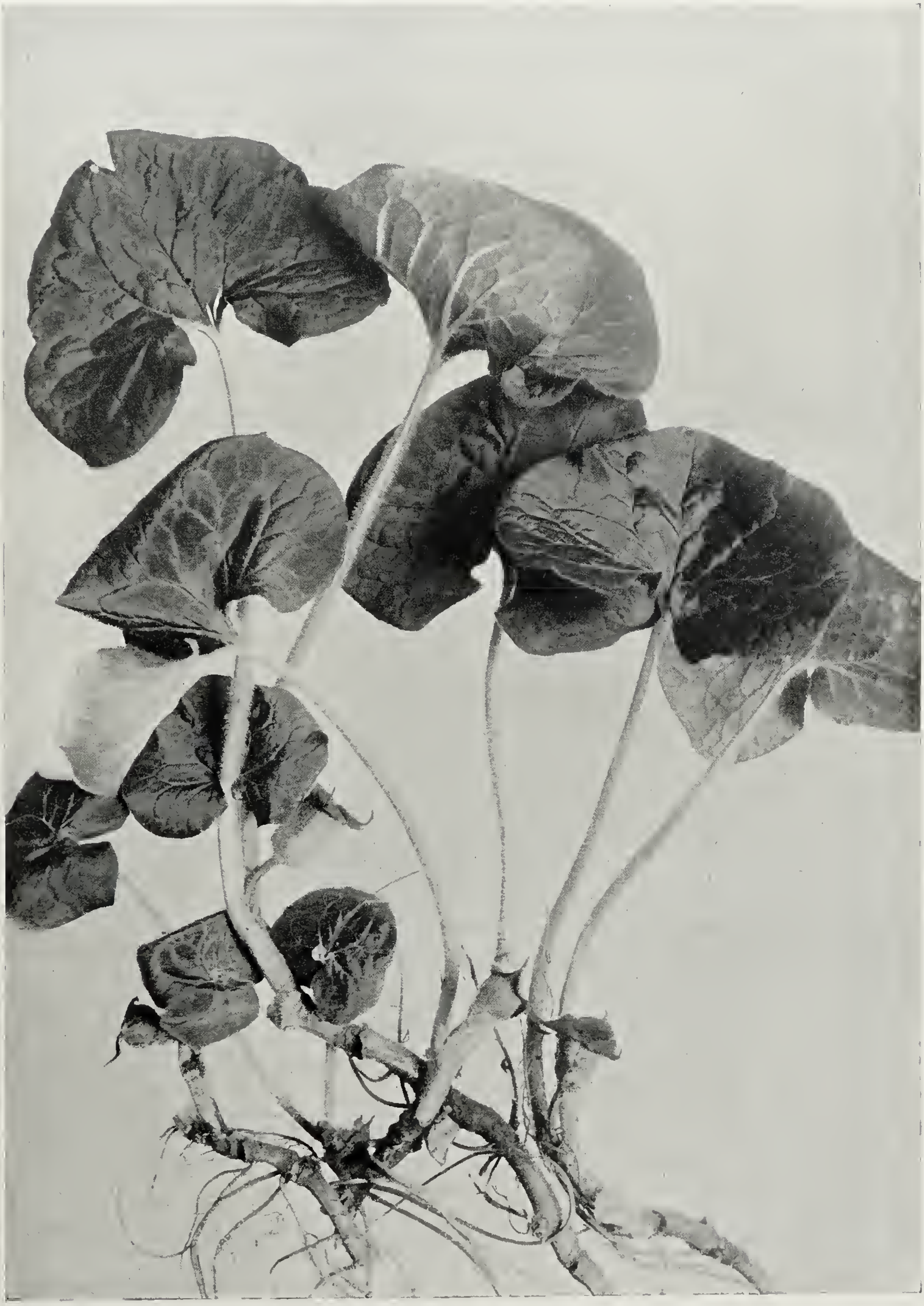


Photo by Henry Troth.

WILD GINGER (*Asarum canadense*), WITH RENIFORM LEAVES.

The brown bell-shaped flowers of this plant are visited by flies, which cross-pollinate them.

PLATE XII.

shaped (*lanceolate*) leaves of the bush which supports the Honeysuckle—viz., the Privet (*Ligustrum*) —and also the egg-shaped (*ovate*) leaves of the Crab-tree (*Pyrus Malus*) which overshadows them (fig. 223). With these last may be contrasted the smooth pale green leaves of the Water-pimpernel (*Samolus Valerandi*), growing on the margin of the stream below. They are broadest and roundest at the apex, and taper towards the base—in other words, are inversely egg-shaped or *obovate* (fig. 223, *c*).

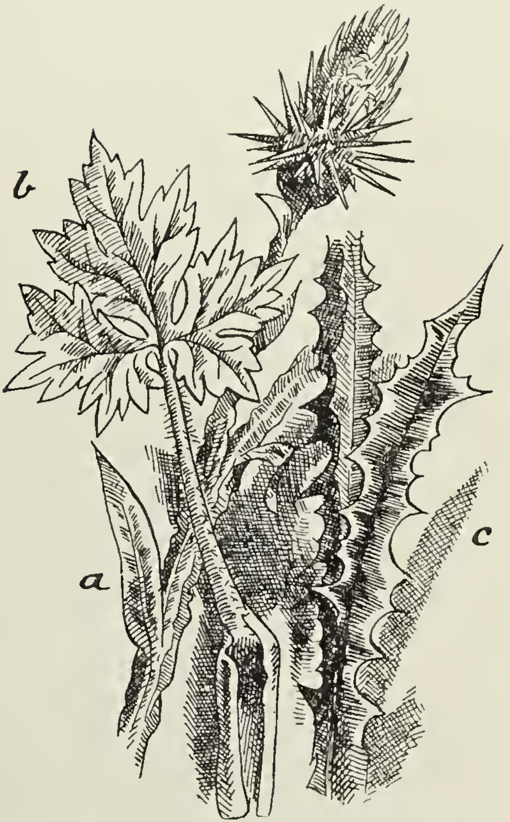


Fig. 221.—(*a*) Sessile leaf of Yellow Star-thistle. (*b*) Amplexicaul leaf of Buttercup. (*c*) Decurrent leaf of Marsh Plume-thistle (*Cnicus palustris*).

How various is Nature! The lane, the meadow, the cornfield, the hedgerow, the brookside, even the tiny stream itself, have something fresh to show at every step. Here are Violets (*Viola*) with their pretty heart-shaped (*cordate*) leaves, though it is vain to seek for flowers on them now. The capricious days of April are the days when the nodding Violet blows. And here is Wood-sorrel (*Oxalis*), which children delight in, though for esculent rather than æsthetic reasons. The form of the bright green leaflets which compose its ternate leaves is just the reverse of the leaf-form of the Violet; for the rounded lobes are at the apex of each. Here the shape is called *obcordate*. You will notice also that there is a notch at the blunt apex of each leaflet, as though a piece had been cut out. All apices which have this peculiarity are *emarginate*.

Do not mistake that pretty yellow-flowered creeper, with quinate leaves and inversely egg-shaped leaflets, for a species of Buttercup. It is the Creeping Cinquefoil (*Potentilla reptans*, fig. 224). You will meet with it on almost every wayside bank, and often, as here, winding its devious way among the linear leaves of the meadow Grasses. That other creeper, with fragrant kidney-shaped (*reniform*) leaves, is a frequent companion of the Cinquefoil, delighting, like its glossy friend, in sunny banks and meadows. Its stalked and downy leaves, whose *crenate* margins should be noted well (fig. 226), were in great request for tea in olden times, when the plant was sold by the "herbe-women of Chepeside" under the

The Stream : showing flowers and leaves of *Iris Pseudacorus.*

names of Gill-by-the-ground, Hay-maid, Cat's-foot, etc. It is the familiar Ground Ivy (*Nepeta Glechoma*). The small yellow flowers which peep through the tall grass in the corner of the meadow belong to a species of *Medicago*—the Spotted Clover of Cornish nomenclature, the *Medicago maculata* or Spotted Medick of botanists (fig. 227, *a*). The little purple spot in the centre of each of its *cuneate* or wedge-shaped leaflets explains the origin of its specific name. Keep a sharp eye on the hedges for a purple-flowered species of this genus, the Lucerne (*M. sativa*), whose serrated leaflets offer good examples of the *oblong* form (fig. 227, *b*). The flattened apices of the leaflets sometimes have a sharp point about the middle, and then they are called *mucronate.*

Daisies (*Bellis perennis*) are everywhere—the commonest of all flowers, yet the flower that is never common! Who of us that loves Nature has not felt something of Chaucer's delight in what a later poet has called the "wee, modest, crimson-tippet flower"—"the little dazy that at evening closes"? gladly confessing with him that this

> is of all floures the floure,
> Fulfillèd of all vertue and honoure;
> And evir like faire and fresh of hewe,
> As well in winter as in summer newe.

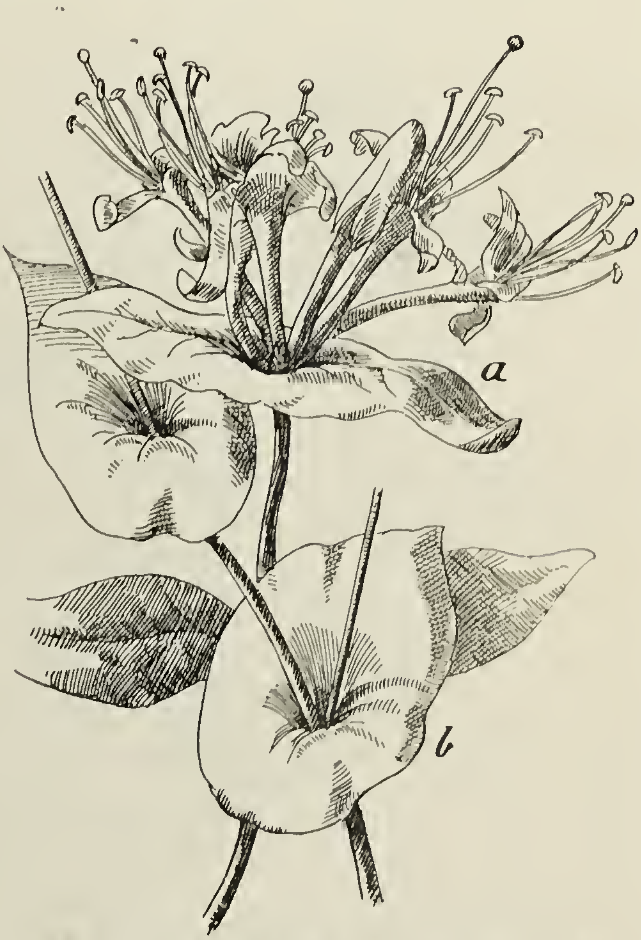


Fig. 222.—(*a*) Connate leaf of Honeysuckle. (*b*) Perfoliate leaves of Hare's-ear.

But it is the broad rounded leaves, whose margins taper down to the base, rather than the pretty pink-tipped florets, that we have to notice (fig. 228). They are called *spathulate*; though you would probably find on examining other specimens that the leaves more generally incline to the inversely ovate form, like those of the Water-pimpernel. The London Pride (*Saxifraga umbrosa*) offers a more fixed type of spathulate leaf; but there is small chance of finding it growing wild in these parts.

Before we cross the narrow footbridge and leave the stream at our back, pluck a leaf of that handsome water-plant with the white three-petalled flowers. It is the Common Arrowhead (*Sagittaria sagittifolia*). *Sagitta* is the Latin word for "arrow," and you have only to glance at the leaf in order to appreciate the fitness of its name (fig. 230). All arrow-shaped leaves are termed *sagittate*; and those who have been much in the country parts of Norfolk and Suffolk will have noticed this attractive form in the leaves of the Tower Mustard (*Turritis glabra*), which grows rather plentifully on the drier banks. The pink-flowered Sheep's-sorrel (*Rumex Acetosella*), which may be met with on dry heaths and downs, has somewhat similar leaves, though the two lobes at the base of the leaf turn outwards, whence they are classed with halbert-shaped or *hastate* leaves (fig. 231). Those aquatic plants with yellow flowers and three-lobed floating leaves, growing beyond the long *sword-shaped* leaves of the yellow flags (*Iris Pseudacorus*), are Water-crowfoots (*Ranunculus aquatilis*). On pulling one of them up, it will be found that its submerged leaves are quite different from the floating leaves, being divided into hair-like segments. Such leaves are called *filiform*; while plants which produce two or more different kinds of leaf on the same stem are said to be *heterophyllous*. We shall have more to say about submerged and floating leaves on a future occasion.

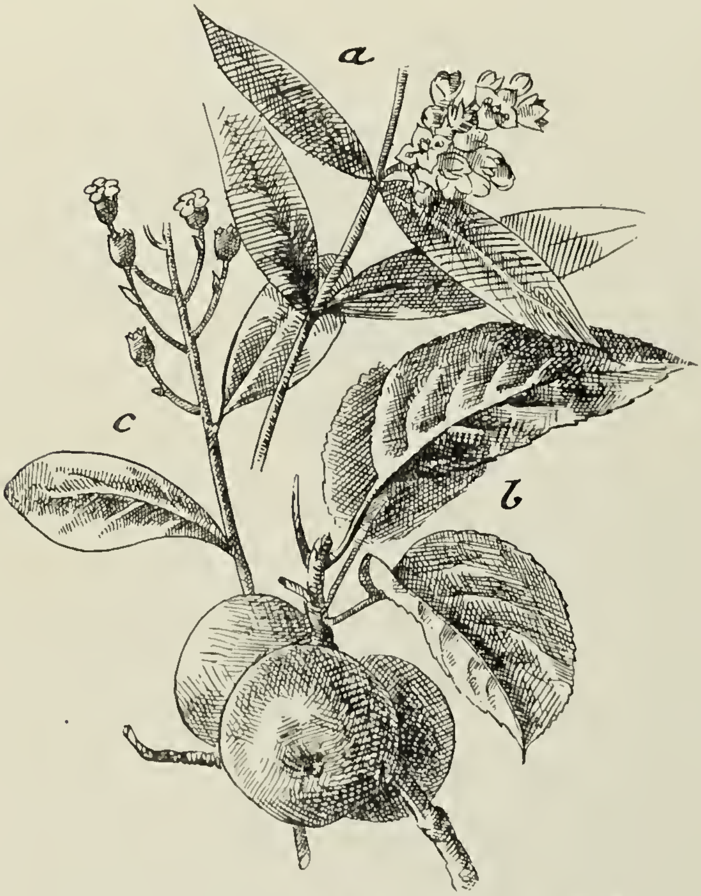


Fig. 223.—(*a*) Lanceolate leaves of Privet. (*b*) Ovate leaves of Crab-tree. (*c*) Obovate leaves of Water-pimpernel.

Beauty is everywhere. Nature's brightest colours meet the eye at every step, for June is emphatically the month of flowers. How they glint and glow among the Barley!—though the farmer who owns the field has little

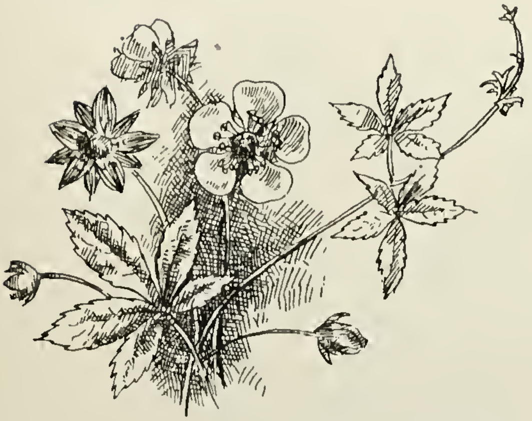


Fig. 224.—Quinate leaves of Creeping Cinquefoil.

praise to bestow upon them—be sure of that!

There are velvet Campions, white and red,
And Poppies, like morning glories spread,
That flash and glance with their scarlet sheen
The stalks of the bearded grain between

—not to mention the numerous representatives of the White Mustard (*Sinapis alba*), Corn-spurrey (*Spergula arvensis*), Hare's-ear (*Bupleurum*), Corn-cockle (*Agrostemma Githago*), Succory (*Cichorium Intybus*), etc. But the Poppies (*Papaver Rhœas*) are pre-eminent. They "fill every interstice between the Barley-stalks, their scarlet petals turned back in very languor of exuberant colour, as the awns, drooping over, caress them" (Jefferies). Observe the irregular leaves of these frail beauties, with their divisions extending very nearly to the midrib (fig. 233, *c*). We call a leaf of this kind *pinnatisect.* If you compare with these a leaf of the White Mustard (*Sinapis alba*), that tallish plant with yellow four-petalled flowers, you will find that it is not so deeply divided, though the divisions, as in the Poppy, follow the direction of the principal veins (fig. 233, *b*). It is *pinnatifid.* Leaves of this plant may also be described as *lyrate*, from their general resemblance to a lyre, their terminal lobes being much the largest, and the other lobes decreasing gradually towards the base.

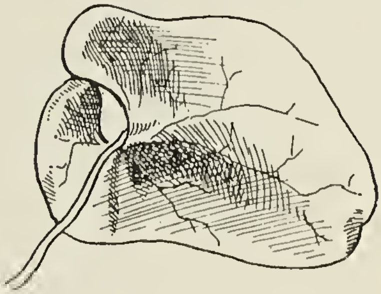


Fig. 225.—Reniform leaf of *Aristolochia.*

Ere quitting the field, secure a specimen of the Corn-spurrey (*Spergula arvensis*). This plant is a friend of farmers when found on meadow-land, but a troublesome obnoxious weed here among the corn. Its small white flowers are very sensitive to atmospheric changes. One writer affirms that he has seen a whole field, which was whitened with its blossoms, entirely changed in appearance by the petals closing when a black

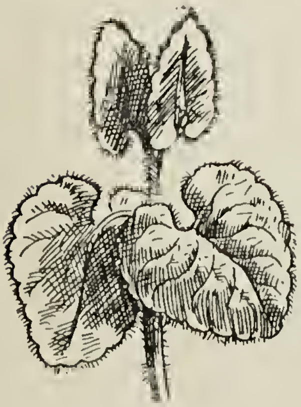


Fig. 226.—Kidney-shaped leaves of Ground Ivy.

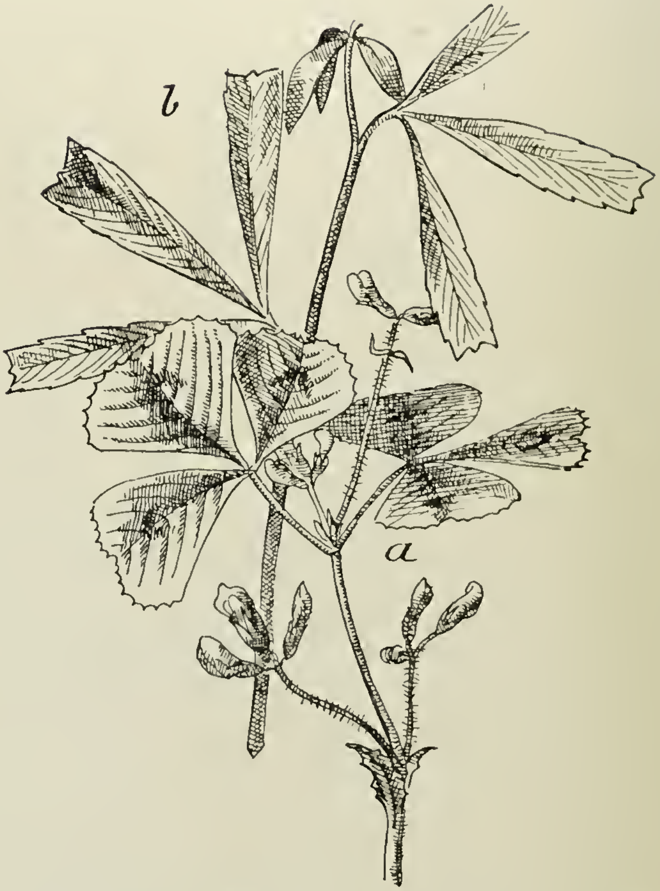


Fig. 227.—(*a*) Wedge-shaped (cuneate) leaves of Spotted Medick. (*b*) Oblong leaves of *Medicago sativa* with mucronate apex.

cloud passed over and discharged a few drops of rain. The plant may always be recognised by its slender *cylindrical* leaves, arranged in *whorls* round the stem (fig. 233, *a*). Leaves which thus grow in whorls are said to be *verticillate*.

Yonder dainty little plant, with bright scarlet flowers, is the Scarlet Pimpernel or Poor Man's Weather-glass (*Anagallis arvensis*), which is no less sensitive to the weather than the Corn-spurrey. Gerarde tells us that the closing of the flowers "betokeneth rain and foul weather; contrarywise, if they be spread abroad, fair weather." But as they have definite hours for opening and closing despite the weather, absolute confidence must not be placed in them as weather prophets. You will notice that the sea-green sessile leaves are placed in pairs on opposite sides of the stem (fig. 234); hence they are described as *opposite*, to distinguish them from *alternate* leaves, which issue singly from their nodes, and which, as they succeed each other, are placed alternately on different sides of the stem. Notice further in the Pimpernel that each pair of leaves crosses the pair immediately below it at right angles, for which reason they are said to be *decussate*. The Lilac (*Syringa vulgaris*), Privet (*Ligustrum vulgare*), and Sycamore (*Acer Pseudo-*

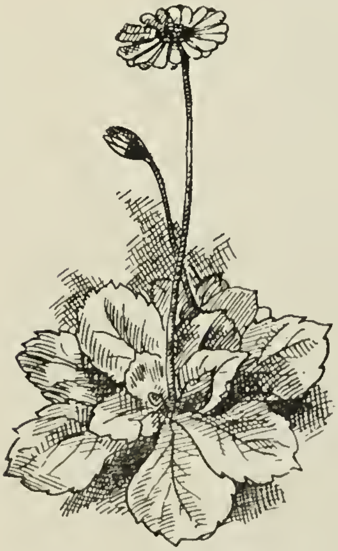


Fig. 228.—Daisy, with spathulate leaves.

platanus) are other familiar examples of decussate leaves.

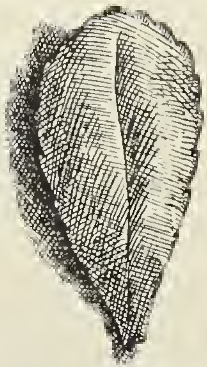


Fig. 229.—Spathulate leaf of London Pride.

Here is the stile, and we may as well step over it, and cross the dusty road to the schoolmaster's cottage. Observe as you do so the plant with prostrate stem and pale greyish lilac flowers. It is the Dwarf Mallow (*Malva rotundifolia*), a lover of farmyards, field borders, and dry waysides. The specific name of the plant is derived from its sub-rotund or *orbicular* leaves—a form which we have not hitherto met with (fig. 235). Among Orientals these leaves have long been in use for culinary purposes; indeed, it has been supposed that this is the plant referred to by Job, when he bitterly complains of the derision of men younger than himself, "whose fathers he would have disdained to have set with the dogs of his flock," and whose employment was once no better than to "cut up mallows by the bushes."

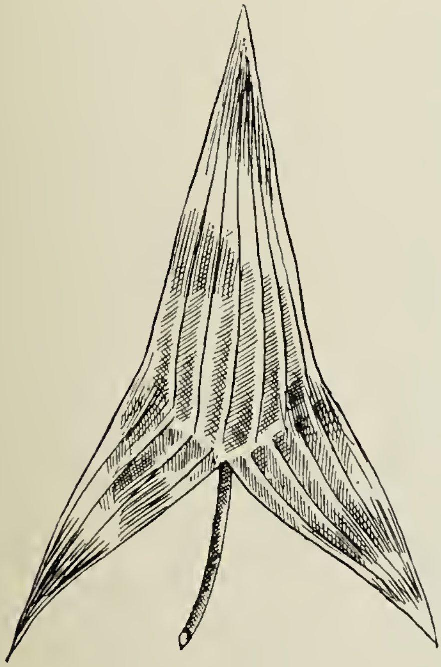


Fig. 230.—Sagittate leaf of Common Arrowhead.

At last we are at the cottage. The little Pearlworts (*Sagina procumbens*), straggling over the garden path, show that the neatly fenced garden has been allowed to run somewhat wild of late. They are among the smallest of our wild-flowers, and their awl-shaped (*subulate*) leaves are scarcely thicker than a pack-thread (fig. 236). The Dandelions (*Taraxacum officinale*) witness of the same neglect, and are disputing every inch of space with their tinier neighbours. Observe the *runcinate* leaves of this weed, the pointed lobes of which turn downwards, whence their name, from *runcina*, a saw. They are also called *radical* leaves, but the term is founded on error, for though they appear to spring from the root, they really arise from the much-shortened stem, and this is the case with most—if

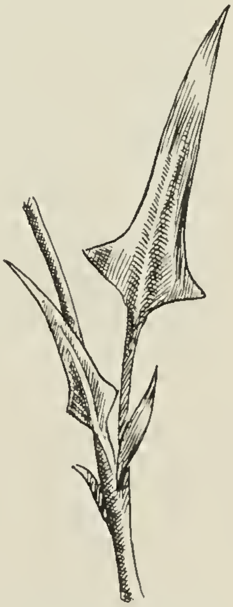


Fig. 231.—Hastate leaves of Sheep's-sorrel.

not all—so-called radical leaves. Where, as in the Pearlwort, it is evident on a superficial examination that the leaves proceed from the stem, they are termed *cauline.*

How gay the Tropæolums look, with their bright orange and yellow flowers, and handsome *peltate* leaves! Peltate (Lat. *pelta*, a shield) is a good name, for the leaves are held aloft by the plant like true shields, the peculiar insertion of the stalk or petiole on the under side of the blade giving them that appearance. The peltate leaves of the Sacred Lotus (*Nelumbium speciosum*), one of the beautiful aquatic plants to be seen in the Victoria House at Kew, sometimes measure as much as two feet in diameter (fig. 238). Those hardy Begonias in the centre bed rival the Tropæolums in brilliancy of colour. Notice well their unequal-sided or *oblique* leaves (fig. 239), which are characteristic of the large family of succulent herbs to which these plants belong.

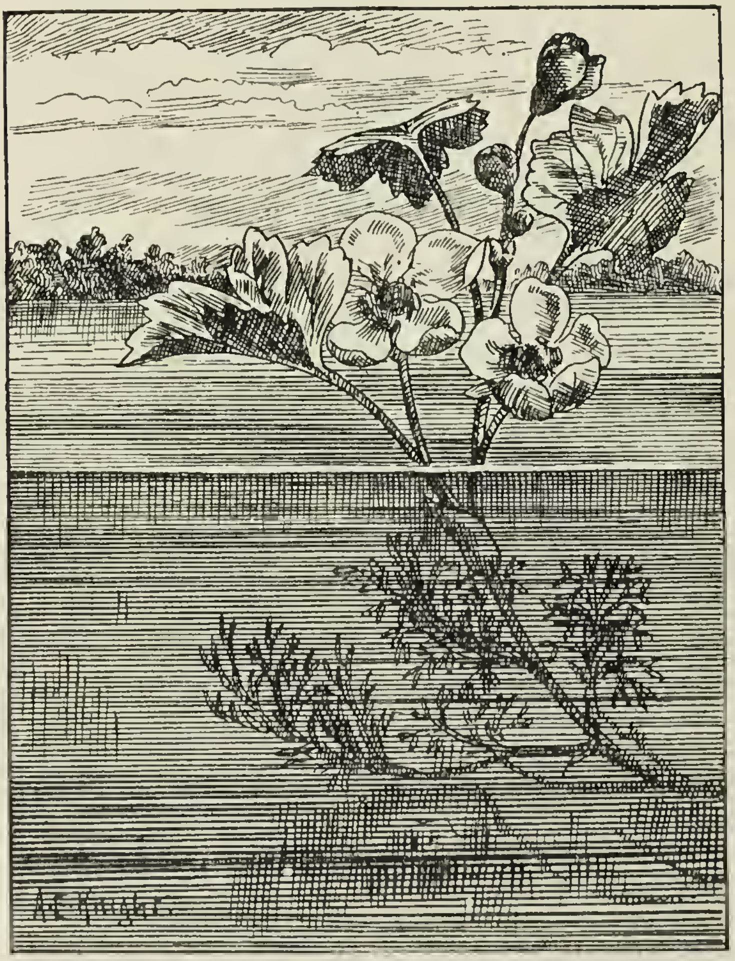


Fig. 232.—*Ranunculus aquatilis.*

Ah, you have pricked your hand against the fence! There was need to warn you of the Holly's *spiny* leaves; but doubtless the offender will be forgiven on account of its associations, and the pleasure which its green and glossy leaves afford when other trees are stripped and brown (fig. 196). Southey says:—

When all the summer trees are seen
So bright and green,
The Holly-leaves their fadeless hues display
Less bright than they;

But when the bare and wintry woods we see,
What then so cheerful as the Holly-tree?

The Holly (*Ilex*) is, in short, an *evergreen*, the leaves of one year remaining on the plant through the winter, until those of the next spring have formed; in which respect it resembles the Ivy and Laurel. Many of the Conifers (Pines, Yews, Junipers, etc.) have needle-shaped (*acicular*) leaves, which persist for many years (fig. 240). The great majority of plants, however, shed their leaves in the autumn—they are *deciduous*.

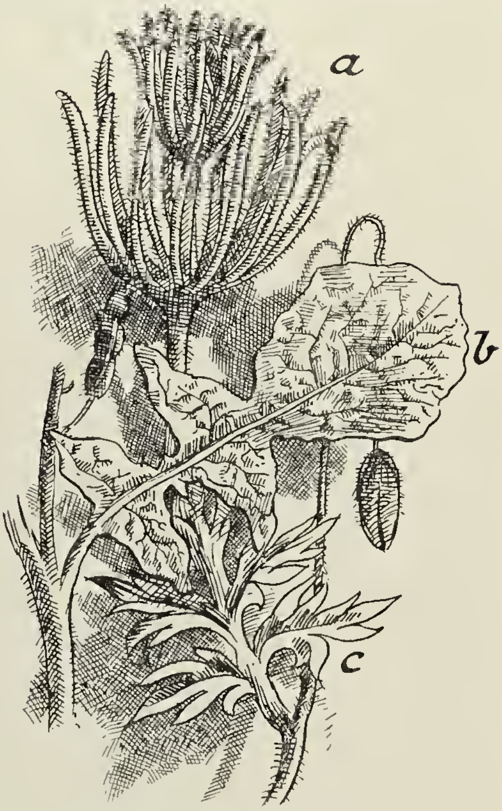


Fig. 233.—(*a*) Whorled cylindrical leaves of Corn-spurrey. (*b*) Pinnatifid lyrate leaf of White Mustard. (*c*) Pinnatisect leaf of Common Red Poppy.

A far more dangerous fellow than our red-berried Christmas friend is the plant whose straggling woody stem finds support against the Holly's tougher boughs. Its drooping clusters of lurid purple flowers, with yellow anthers united into a cone, at once proclaim it to be the Woody Nightshade, or Bittersweet (*Solanum Dulcamara*). Notice its upper leaves, the small basal lobes of which are separated from the blade so as to form two little wings, or ears. Such leaves are called *auriculate* (fig. 241). This plant is not the Deadly Nightshade, but persons are said to have been poisoned by eating its roots.

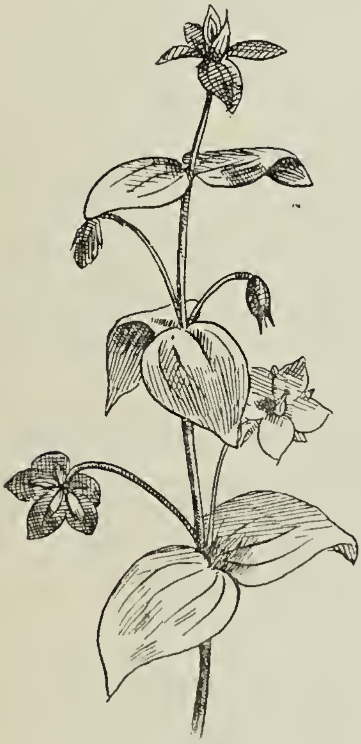


Fig. 234.—Decussate leaves of Scarlet Pimpernel.

There, within a finger's length of the nearer of the Tropæolums, is a Saxifrage; but not the one which we were wanting just now. It is the kidney-

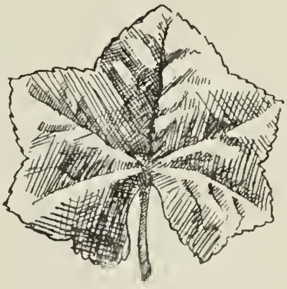


Fig. 235.—Orbicular or sub-rotund leaf of Dwarf Mallow.

The Schoolmaster's Cottage.

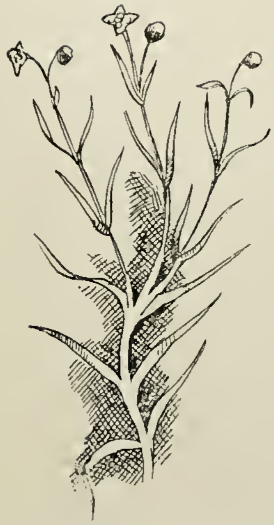


Fig. 236.—Subulate leaves of Pearlwort.

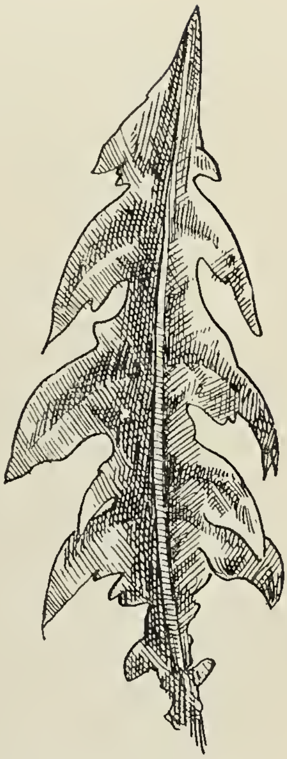


Fig. 237.—Runcinate leaf of Dandelion.

shaped species (*Saxifraga Geum*), and the sharply toothed or *dentate* margins of its leaves (fig. 242) should receive attention, as they are the first instances of such a margin that have come before us. You will perceive that the teeth point outwards, and not, like the teeth in a serrated margin (compare fig. 211), towards the apex of the leaf.

It is fortunate that the garden contains a specimen of the Tulip-tree (*Liriodendron tulipifera*). Notice the curiously abrupt or truncated termination of the leaves, which gives them the appearance of having their upper extremities cut off. No plant furnishes better examples of a *truncate* leaf than this (fig. 243). We would press the importance of always noting the forms of leaf apices when preparing schedules of plants. Trivial points of this kind are often of

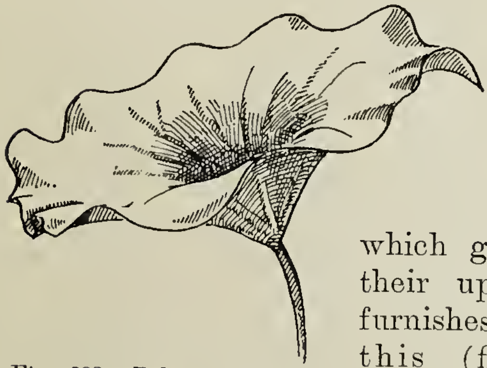


Fig. 238.—Peltate leaf of *Nelumbium speciosum*.

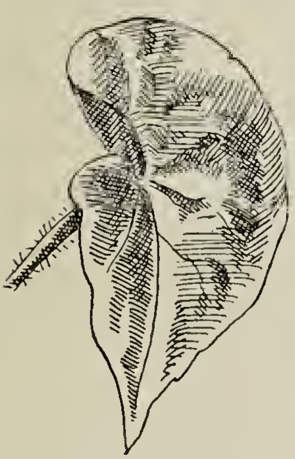


Fig. 239.—Oblique leaf of Begonia.

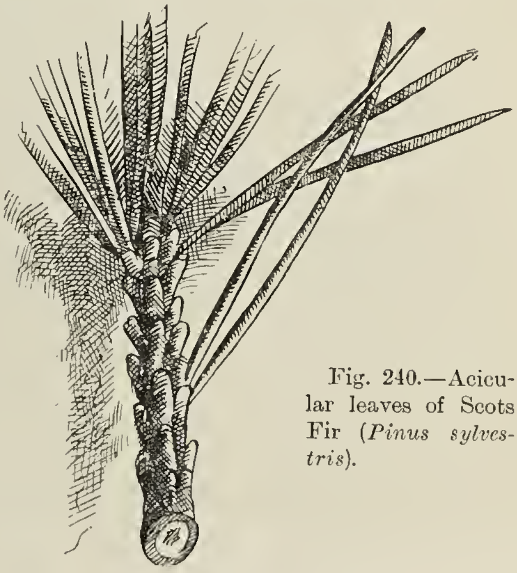


Fig. 240.—Acicular leaves of Scots Fir (*Pinus sylvestris*).

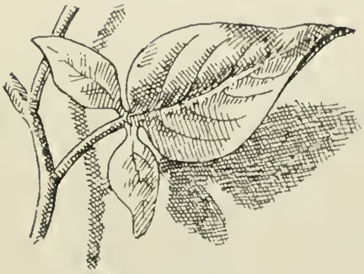


Fig. 241.—Auriculate leaf of Woody Nightshade.

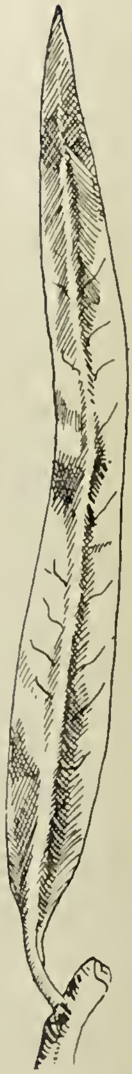


Fig. 244.—Linear lanceolate leaf of Osier with acuminate apex.

assistance in determining species and varieties. In addition to the forms already described—namely, the mucronate, emarginate, and truncate (pp. 187, 189, and 197)—four others may be briefly alluded to. Two of these—the *acute* and *obtuse* (*i.e.*, blunted)—are extremely common, and hardly need to be described; the third is the *retuse*, which differs from the obtuse in having a broad, shallow notch in the middle, as may be seen in the leaves of the Red Whortleberry (*Vaccinium Vitis-Idæa*); and lastly, the *acuminate*, in which the apex narrows suddenly and lengthens into a point or *acumen*. A somewhat extreme example of the latter form is furnished by the Mexican shrub *Phyllonoma ruscifolium*, which, however (as we saw earlier—p. 174) is chiefly interesting because of the peculiar growth of its flowers, which are produced in little bunches on the upper surface of the midrib, just below the base of the acumen. If, as some have suggested, the lower part of the leaf is really a cladode, then the acumen alone is the true leaf, and should be described as lance-shaped rather than acuminate. However, it is quite unnecessary to go so far afield for specimens of leaves with acuminate apices. Two of our British Willows—the Osier and White Willow (*Salix viminalis* and *S. alba*)—offer excellent examples, particularly the former (fig. 244); and although we have passed neither of these on the way, the White Willow is so common throughout the country that there need be no difficulty in obtaining specimens.

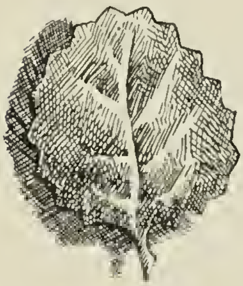


Fig. 242.—Kidney-shaped (reniform) leaf of *Saxifraga Geum*, with dentate margin.

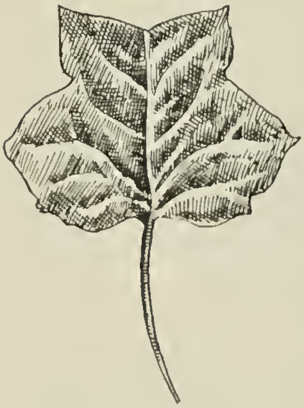


Fig. 243.—Truncated leaf of Tulip-tree.

So ends our excursion. All the principal leaf-forms have now been touched upon, and we have really travelled over most of the ground covered by the text-books. We trust that what the present plan has lost in method it has gained in interest. To those who would pursue the subject further (and let it not be forgotten that a sound knowledge of plants presupposes a thorough acquaintance with the forms of leaves), we would recommend the practice of keeping a scrap-book, in which the leaves collected may be mounted and arranged. Let one page be devoted to net-veined leaves; another to parallel-veined; a third and a fourth to compound and single leaves respectively; a fifth to the different kinds of margin; a sixth to the different kinds of apex; and so on, till every variety of shape is represented and classified. In this way one is brought face to face with many curious and instructive facts, of which even the fullest treatises say nothing, and the foundation of a trustworthy knowledge of botany is laid that will be found increasingly valuable the further such investigations are pushed. Thus, too, will one's acquaintance with Nature herself become more and more extended, and the facts which we have been accumulating by steady patience and reverent study will yield in the near future an abundant harvest of joy.

CHAPTER IX

THE LEAF IN RELATION TO ITS ENVIRONMENT

A change in the surroundings of any plant can so react upon it as to cause it to change. By the attempt, conscious or unconscious, to adjust itself to the new conditions, a true physiological change is gradually wrought within the organism.—PROFESSOR DRUMMOND.

ALTHOUGH the previous chapter was devoted chiefly to the consideration of the forms of leaves, we must now briefly resume the subject in order to refer to a few forms not hitherto noticed—curious and exceptional forms, of which, in most cases, our British plants afford no examples. This will pave the way to the subject more especially before us—namely, the adaptation of foliage leaves to their environment.

The subject of environment, in so far as the *sustaining* of vegetable life and vigour is concerned, has been already dealt with in preceding chapters, where we have seen that, while in the plant itself resides the principle of Life, in the environment are found the *conditions* of Life; and that without the fulfilment of those conditions—in other words, without the regular supply of heat, air, water, inorganic substances, and so forth, to the living tissues, the plant would languish and die. This part of the ground—the most important part without doubt—we do not propose to retrace. What will be before us in the pages immediately succeeding is the effect of environment in *modifying the structure* rather than in sustaining the life of the plant—the effect, indeed, which is evident in what is called Variation. This may appear to be anticipating, but many of the morphological facts which have been grouped together for preliminary mention are intimately connected with the phenomena of Variation.

Of the multifarious leaf forms which the Vegetable World presents, few, perhaps, are so singular as those of the *Sarracenias* and *Nepenthes*. These have already been treated at considerable length in Chapter IV., when the insectivorous habits of plants were before us; and we may therefore dismiss them here in few words. In both genera the insect-catching pitchers are themselves the leaves, but they have this difference: in *Sarracenia* the tall trumpet-shaped portion of the leaf is looked upon as an expansion of the petiole or leaf-stalk, and the lid as the lamina or blade; while in *Nepenthes* the pitcher is regarded as a modification of the lamina, the lid being a special prolongation of the apex. In the Australian Pitcher-plant (*Cephalotus follicularis*) the parts of the singular tankard-shaped leaves correspond rather with those of *Sarracenia* than of *Nepenthes* (fig. 245). Leaves of the pitcher class are called *ascidiform*, from the Greek *askidion*, a little bottle (figs. 245-247).

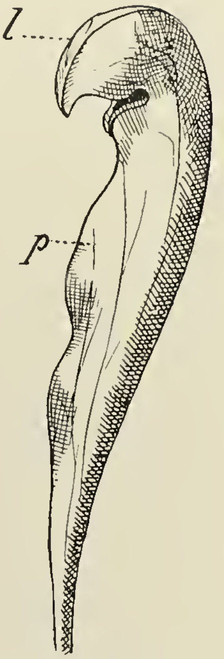


Fig. 246.—Ascidiform leaf of *Sarracenia*. (*l*) Lamina. (*p*) Petiole.

Recently, at Kew, one of the attendants pointed out to us a species of *Laportea*, lately arrived from New Guinea, each of the leaves of which was finished off at the apex as a little cup (fig. 248); but we were unable to ascertain what purpose these ascidiform appendages fulfil in the economy of the plant. They can hardly be insect-traps like the pitchers of *Nepenthes*, as the downward curve of the leaf gives the cups an inverted position. One would like to know whether, in their natural habitat, a vertical position is ever assumed by the leaf.

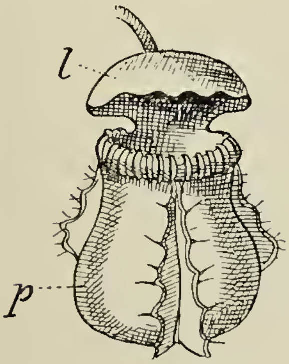


Fig. 245.—Ascidiform leaf of *Cephalotus*. (*l*) Lamina. (*p*) Petiole.

If, as is generally agreed, the trumpet-shaped portion of the leaves of *Sarracenia* is really an expansion of the petiole, it would be botanically described as a *phyllode*, and thus would answer to the leafy expansion of the petiole of certain Australian species of *Acacia*—as, for instance, *Acacia melanoxylon* (fig. 249), which, when young, possess bipinnate leaves with flattened petioles, but which are succeeded by others more phyllode-like as the plant grows older (fig. 249), until at last the leaflets (*pinnæ*) entirely disappear, and phyllodes only are produced. The phyllodes have the appearance, and perform all the functions, of normally developed foliage-leaves.

There is a tendency among the Acacias, as well as some closely allied plants, to develop different forms of leaf *on the same individual* with a

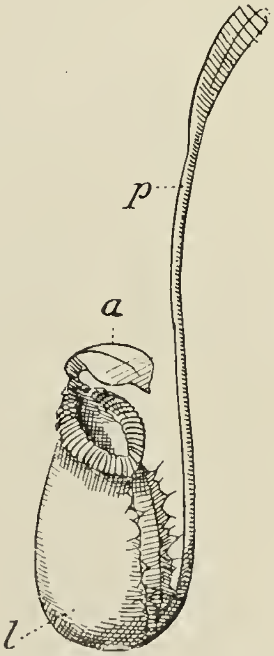


Fig. 247.—Ascidiform leaf of *Nepenthes*. (*a*) Apical prolongation. (*l*) Lamina. (*p*) Petiole.

capriciousness that is extraordinary. Not only will you find pinnate, bipinnate, and tripinnate leaves on the one plant, but instances are not uncommon in which a single leaf inclines to all these forms at once. The leaf of the Honey-locust-tree (*Gleditschia triacanthos*) is a case in point (fig. 250). The tree is a native of North America, where its long thorny branches wage incessant war with the unarmed Maple-trees, in close proximity to which it is usually found growing. Surely if plants, like animals, are liable to be affected by changes of the moon, the Honey-locust-tree has fallen under the baneful influence! It reminds one of those old Lime-trees (*Tilia platyphyllos*) mentioned by Dr. Burnett, which, instead of developing the cordate or obliquely cordate leaves of this species, regularly put forth leaves of a hooded (*cucullate*) form. These trees were growing in the churchyard of Seidlitz, in Bohemia, sixty years ago—possibly they are still growing there. In Burnett's time the peasants affirmed that the production of the hooded leaves was due to the fact that some monks from a neighbouring convent had been hanged on the trees!

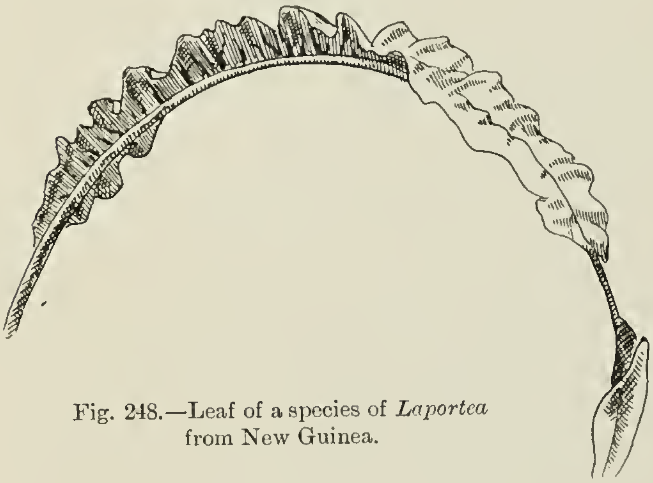


Fig. 248.—Leaf of a species of *Laportea* from New Guinea.

Those who have what Americans would call "a big swallow" may be satisfied with this explanation, but the diversity of form in the normally heterophyllous leaves of *Gleditschia triacanthos*, *Acacia heterophylla*, etc., has no such convenient story to account for it, nor are we in a position to suggest a probable explanation—indeed, it is only when we turn to aquatic plants that the special usefulness of heterophyllous leaves becomes apparent. Mention has been made of the Water-crowfoot (*Ranunculus aquatilis*), whose submerged leaves are so different from the floating ones, the former consisting merely of narrow thread-like segments, while the latter are three-lobed with dentate margins. This difference may be partly accounted for by the fact that the submerged leaves, being less favourably situated for light than the others, make the most of the rays that visit them by assuming the shredded form. It has been further remarked that aquatic plants which develop filiform leaves are usually, if not always, found in *running* water; and how well are they adapted for such environment!—yielding readily to the current, and participating in its movements without injury. These

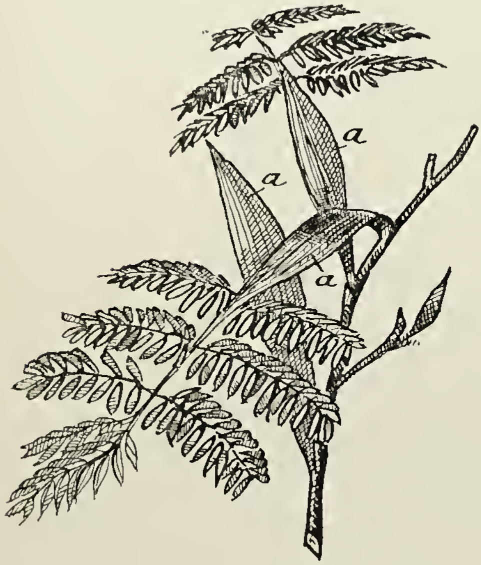


Fig. 249.—Branch of *Acacia melanoxylon*. (*a a a*) Phyllodes.

observations apply equally to the Potamogetons (*P. heterophyllus*, *rufescens*, and *spathulatus*), to the Water-caltrops (*Trapa natans*), and to the Cabomba (*Cabomba aquatica*, figs. 251, 252). The latter may be studied to advantage in the Victoria House at Kew.

The buoyancy of floating leaves is, in not a few cases, secured by special air-channels, which may be situated either in the blade or the leaf-stalk—more frequently the latter. In the Brazilian Pickerel-weed (*Pontederia crassipes*), the swollen and hollow leaf-stalks act as floats to the whole plant, which, as it does not root itself to the mud, is carried hither and thither by wind and current like a rudderless ship. In *Desmanthus natans*, an aquatic plant of the Leguminous order, the stem takes the form of "a large-celled, spongy, air-containing mantle," which subserves the same purpose as the leaf-stalks of the Pickerel-weed, and is, in fact, a veritable swimming apparatus.

As a consequence of their situation, aquatic plants imbibe much more water than land plants, and the transpiration is proportionately greater. One sees in this fact the advantage of their broad, flat, floating leaves, which, lying side by side on the surface of the water, present so large a field for the sun's operations; for it will be remembered that transpiration takes place through the stomata, and that these organs, in aquatic plants, are placed on the upper surface of the leaves. When it is stated that a single Water-lily-leaf of very ordinary size may contain as many as eleven and a half million stomata, one may realise what liberal provision is made for the removal of superfluous moisture.

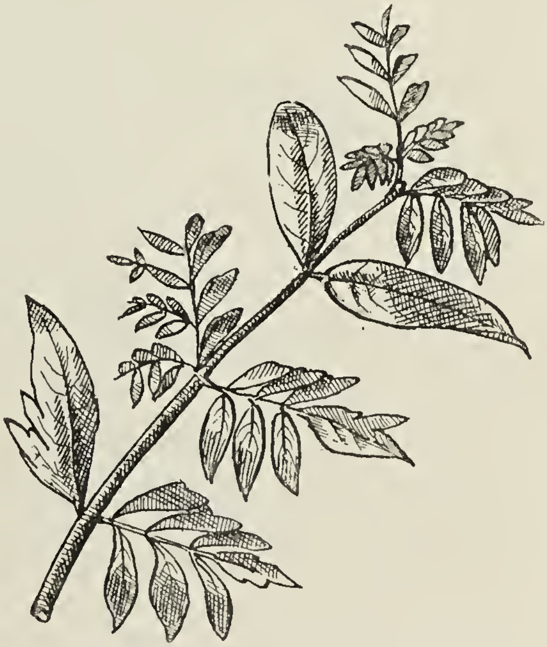


Fig. 250.—Leaf of Honey-locust-tree, showing singular blending of pinnate, bipinnate, and tripinnate forms.

Still further to assist this end, the under sides of many floating leaves are coloured violet or crimson by a pigment known as *anthocyanin* (sometimes called *cyanophyll*), which has the remarkable property of changing light into heat, and thus of giving increased warmth to the parts where transpiration is going on. This foliage painting is seen to perfection in the magnificent leaves of the *Victoria regia*. Our drawing (see p. 205), which was made from one of the specimens at Kew, fails to do justice to the tropical queen, which, indeed, must be seen in its native habitat to be properly appreciated. The plant was first discovered by Sir Robert Schomburgk during his explorations in South America on behalf of the Royal Geographical Society; and the distinguished traveller thus records the event: "It was on January 1st, 1837, while contending with the difficulties which Nature interposed in different forms to stem our progress up the River Berbice (lat. 4° 30′ N., long. 52° W.), that we arrived at a part where the river expanded and formed a currentless basin. Some object on the southern extremity of this basin attracted my attention, and I was unable to form an idea what it could be; but animating the crew to increase the rate of their paddling, we soon came opposite the object which had raised my curiosity, and behold, a vegetable wonder! All calamities were forgotten; I was a botanist, and felt myself rewarded! There were gigantic leaves, five to six feet across, flat, with a broad rim, light green above and vivid crimson below, floating upon the water; while in character with the wonderful foliage I saw luxuriant flowers, each consisting of numerous petals, passing in alternate tints from pure white to rose and pink. The smooth water was covered with the blossoms, and as I rowed from one to the other I always found something new to admire. . . . Ascending the river, we found this plant frequently, and the higher we advanced the more gigantic did the specimen become; one leaf we measured was 6 ft. 5 in. in diameter, the rim five and a half inches high, and the flowers a foot and a quarter across."

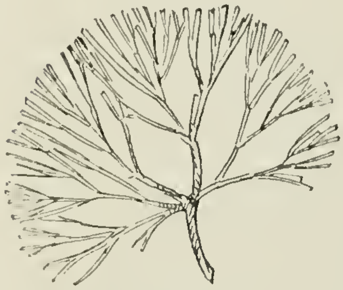


Fig. 251.—Submerged leaf of *Cabomba aquatica*.

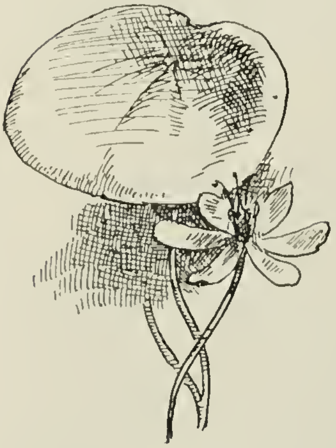


Fig. 252.—Pellate aerial leaf of same, with flower.

The under surfaces of these leaves—as, indeed, of nearly all floating leaves—afford resting-places for numberless aquatic insects and snails; while certain birds which prey on fish use the leaves as rafts. The

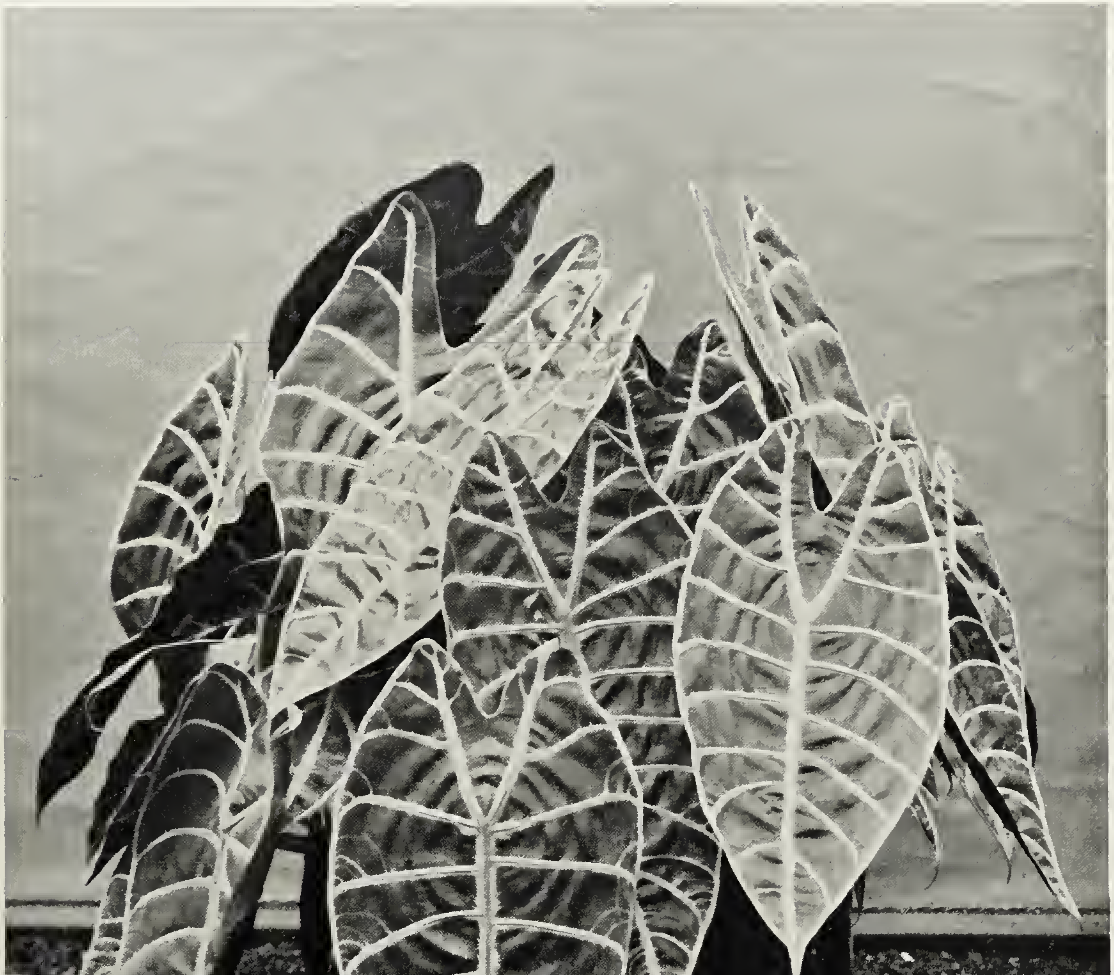
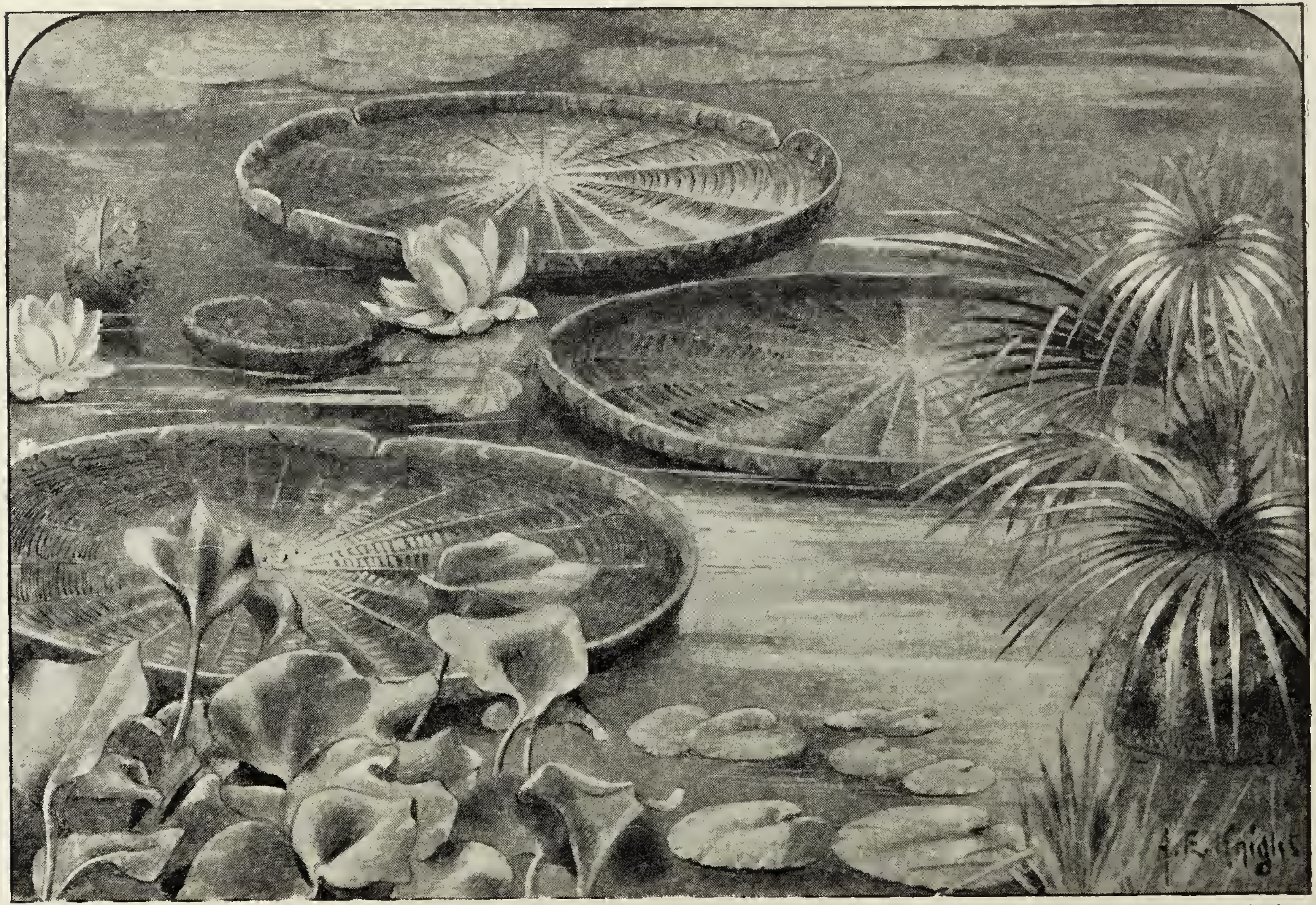


Photo by F. C. Taylor.

Alocasia spectabilis.

An herbaceous plant belonging to the extensive order Aroideæ. The large radical leaves of this plant are beautifully variegated.

PLATE XIX.



The Giant Water-lily (*Victoria regia*). At the base of the picture, left-hand corner, is shown a Brazilian aquatic plant (*Pontederia crassipes*). The palm on the right of picture is *Trachycarpus excelsa*.

French traveller Marcoy, who saw large numbers of the Victoria Lilies on the Nuña Lake, Peru, likens the collective effect of the leaves to a splendid carpet, on which, to quote his own expression, "quite a multitude of stilt-plovers, ibises, jacanas, anhunas, savacas, Brazilian ostriches, and spoonbills disported themselves." The jacanas mentioned by Marcoy are the *Parræ* of naturalists—wading birds, somewhat analogous both in structure and habits to the European water-hen, and their light bodies and long toes enable them to walk on the floating leaves with as much facility as if they were on land.

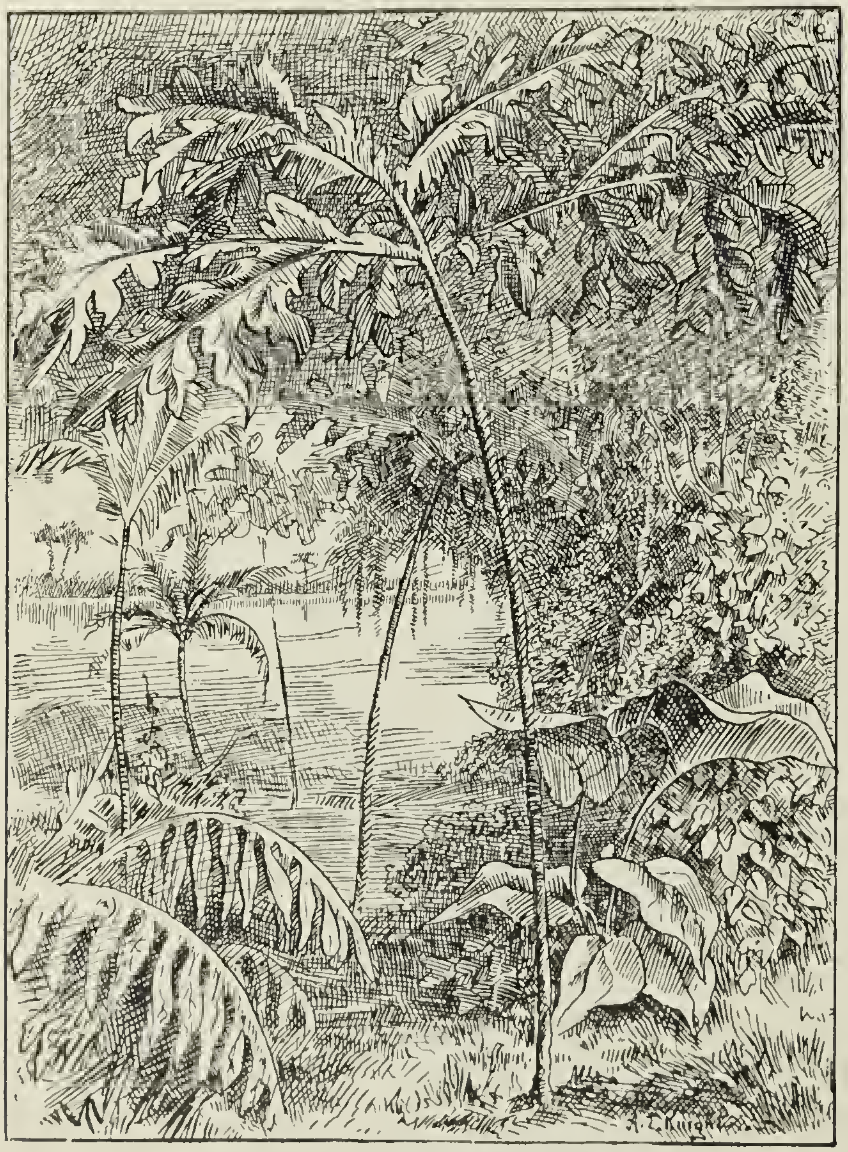


Fig. 253.—Giant Aroid (*Godwinia Gigas*).

Large as are the leaves of the Victoria Lily, they are by no means the largest known. The *Godwinia* (or *Dracontium*) *Gigas* (fig. 253), a species of Arum discovered in Central America by Dr. Seeman so recently as 1869, produces a leaf no less than fourteen feet long. Its stalk, which is beautifully mottled with purple and yellow, has been compared to a huge snake standing erect at the bidding of an Eastern charmer. But there are greater leaves even than this. At Kew, not long since, one of the Sago Palms bore fronds* which were upwards of forty feet in length; and we believe that even larger ones have been met with. Nevertheless, the Victoria Lily is the largest of floating leaves, and well deserves all the praise that has been lavished upon it.

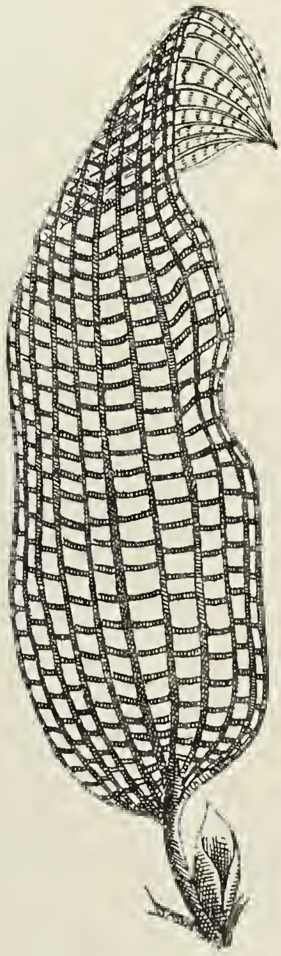


Fig. 254.—Lattice leaf of *Ouvirandra fenestralis.*

Thirty years ago the eminent German botanist Hildebrand gave an account of some interesting observations on the physiology of the floating leaves of *Marsilea quadrifolia* in the *Botanische Zeitung.* He found that when a plant of this species is sunk beneath the surface of the water, so that all the leaves are more or less deeply covered, those leaves which are fully developed at the time of immersion remain unchanged, while those which are not so far advanced undergo a remarkable change, the petioles gradually lengthening in succession according to their position on the stem, and soon over-topping those which were already formed. At first the four leaflets do not increase, but presently they begin to enlarge, and by the time the surface of the water is reached they exceed in size the ordinary leaves, forming a four-rayed star on the surface. While the petioles of the ordinary leaves are stiff, so that they stand erect out of the water, these floating leaves are weak and flexible, like those of water-lilies, allowing the leaf to maintain its position on the surface with the rise and fall of the water. Their upper surface is shining and coated with wax, so that the water flows off them. If immersed in deeper water, the petioles will lengthen still further even to the extent of three feet.

Before passing from water-plants, we must call attention to that delicate Madagascar aquatic, the Lattice-leaf-plant (*Ouvirandra fenestralis*), which is remarkable from the fact that the network of its leaves, instead of being filled up with tissue (parenchyma) in the ordinary way, is left open, the chlorophyll in each leaf being contained in a thin

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* In speaking of Palm-leaves as "fronds," we use popular language. In botanical terminology a frond is the leaf of a Fern or other Cryptogam. The poet Whittier has the lines:—

> I know not where His islands lift
> Their fronded Palms in air.

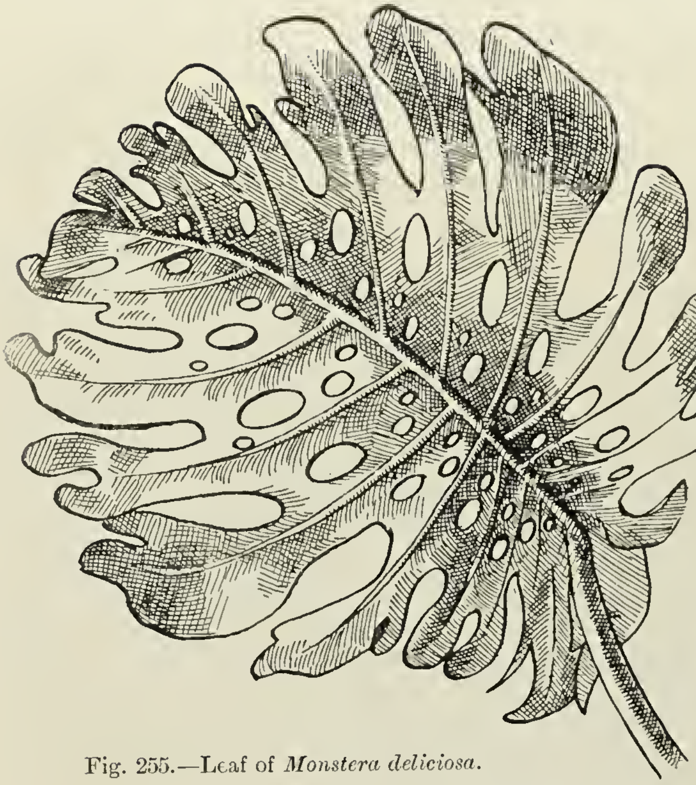

Fig. 255.—Leaf of *Monstera deliciosa*.

layer of cells which covers the strands (fig. 254). The plant is entirely submerged, and when viewed from above has the appearance of a large oval piece of green net spread out upon the mud in which its roots are fixed. This appearance is due to the procumbent position of the lace-like leaves, which form a rosette round the short mud-embedded stem. They remind one, as Kerner aptly says, of autumn leaves which have fallen into water and lost all their parenchyma through maceration, the skeletons alone remaining. It may be added that a few of the Seaweeds (*e.g.*, *Agarum Gmelini* and *Thallasiophyllum Clathrus*) offer the same peculiarity as *Ouvirandra*, their fronds being perforated in a very beautiful manner.

The existence of leaf-holes in certain land-plants is also to be noted. Such perforations are confined to the large upper leaves of tropical plants like the Aroids (*Monstera deliciosa*, etc., fig. 255), which, but for this provision, would entirely exclude the sun from the lower leaves, and thus impair the activity of the green tissues. The deep incisions and clefts which give such beauty of outline to palmatisect and pinnatisect leaves evidently subserve a similar purpose; while the disposition of the leaves on the stem, and of the leaflets on the petiole, has definite relation to the same important end.

It is highly probable, also, that the *laciniated* (fringed) forms of specially large leaves bear the same relation to the wind that the thread-like forms of submerged leaves do to water—that is, they present no large unbroken surfaces to the varying currents of air, and thus escape rupture during heavy storms. In many cases tearing is prevented by a strengthening of the epidermal cells, particularly at the edges of the leaves, where of course the strain is greatest. This is well illustrated in the leathery leaves of the Holly (*Ilex*) and the Indiarubber-plant (*Ficus elastica*, fig. 256).

Leaves which assume a vertical position are specially exposed to the violence of the wind. The currents of air usually take a course which is parallel to the earth and therefore strike against such leaves at right angles, so that special adaptations are needed to enable the latter to retain their upright position. In many of the Grasses—the Common Reed (*Phragmites communis*) may serve as an example—the leaf-blades turn on the haulms* like weathercocks. In the Reed-mace (*Typha latifolia*) the leaf is spirally twisted, so that a whole surface is never presented to the wind—an arrangement the advantage of which is sufficiently obvious. In other plants, protection from the wind is secured by the leaf being hollow. It is well known that a tube resists flexion more effectually than a solid body; and tubular or *fistular* leaves will maintain their erect position even in the roughest weather. Examples of the fistular leaf are presented by the Common Onion (*Allium Cepa*) and other bulbous plants. In the Purple Meadow-crocus (*C. vernus*) the edges of the leaf roll over towards the white central stripe so as to form a sort of double tube; and thus this little harbinger of spring is able "to take the winds of March with beauty" (fig. 257).

When speaking of buds, we showed that the chief purpose of the woolly growth which often covers them is to protect the young leaves from the cold winds and nipping frosts of winter. It

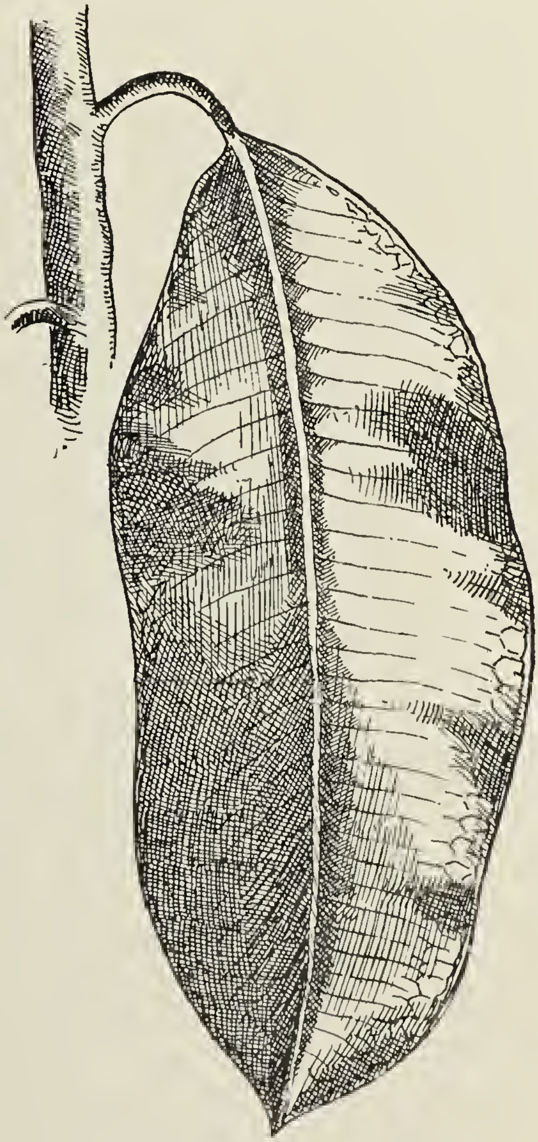

Fig. 256.—Leaf of Indiarubber-plant.

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* A haulm is the stalk of a grass of any kind. The word is derived from the Danish *halm*, which is cognate with the Lat. *calamus* and the Greek *kalamos*, reed.

must not be imagined, however, that this is also the chief purpose of the wool and hairs which cover more or less thickly the surfaces of many adult leaves. Heat, rather than cold, is the danger to which the mature leaf is exposed, and the purpose of its covering hairs is not so much to promote warmth as to prevent excessive exhalation. Just as the succulent stems of the Cactuses and many tropical Euphorbias are provided with a leathery membrane to retard evaporation, so, and for the same reason, a great number of leaves are provided with hair-like structures, which, by shielding the epidermis from the direct rays of the sun, reduce transpiration and save the leaves from untimely desiccation.

Those who have never studied under the microscope the singular forms of these covering hairs, have pleasures offered to them for many a winter evening. Possibly a glance at the illustrations which accompany this part of our text will help to kindle interest in the subject. Fig. 261 represents some *simple* hairs of a species of *Brassica*; fig. 262 some *forked* hairs of the Whitlow Grass (*Draba verna*); and fig. 267 a *stellate* hair of the pretty Alpine Madwort (*Alyssum spinosum*). In these three specimens the hairs are unicellular, but multicellular hairs are met with in a large number of plants. When the cells grow together in a line, like the beads of a necklace, the hairs are said to be *moniliform*. Of this kind are the epidermal hairs of the Marvel of Peru (*Mirabilis Jalapa*, fig. 265) and of the Virginian Spiderwort (*Tradescantia virginiana*, fig. 266). When the cells spring from a common point, as in the Cretan Horehound (*Marrubium creticum*, fig. 263), the hairs are said to be *tufted*. *Branched* hairs, which need no describing, are found in several plants. They give the downy (*tomentose*) appearance to the leaves of *Nicandra anomala*, a Peruvian plant of medicinal value (fig. 264), and to the decurrent leaves of the Bastard Mullein (*Verbascum thapsiforme*). In a few plants of succulent habit, like the South African *Rocheas*, excessive evaporation is prevented by the development of special flinty cells on the epidermis of the thick fleshy leaves (fig. 268). They are many times larger than the ordinary epidermal cells, and their walls are largely composed of silica. A covering of this kind is simply the salvation of its possessor in time of drought. Not that fleshy leaves are ill-adapted to

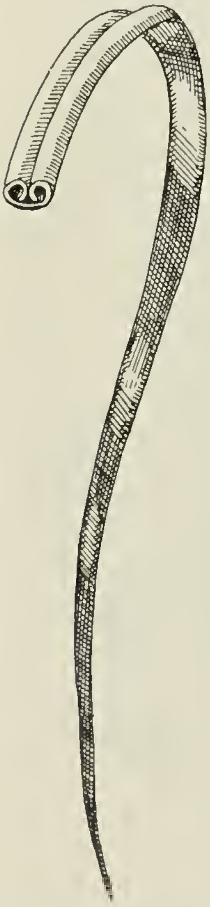
Fig. 257.—A two-barrelled fistular leaf.

dry climates; the reverse is the case, the transpiring surface of such leaves being much smaller than if they were flattened out into thin and spreading forms. Yet even the smaller surface needs to be protected, and this it is which gives its value to the flinty armour.

The vertical position which many leaves assume is likewise a means of checking excessive transpiration. One has met with the expression, "the *shadowless* forests of Australia," and the phrase is not inappropriate, for the leaves of many Eucalyptus-trees and Acacias (the chief timber-trees in Australian woods) do not assume a horizontal position like the leaves of most European forest-trees, but are placed vertically on edge; and thus the shadows which they cast at midday are reduced to a mere line. This, as we need scarcely add, is due to the fact that the rays of light fall upon the upturned edges of the leaves and not upon the broad surfaces of the blades.* The latter, indeed, escape altogether the meridian sun, though they get the full benefit of his less scorching rays at the beginning and close of the day.

The interesting Compass-plant (*Silphium laciniatum*) should not be forgotten when speaking of the position assumed by leaves in reference to transpiration. Longfellow's *Evangeline* contains a graceful description of the plant, which is widely distributed over the North American prairies:—

> Look at this delicate plant that lifts its head from the meadow,
> See how its leaves all point to the north, as true as the magnet;
> It is the Compass-flower, that the finger of God has suspended
> Here on its fragile stalk, to direct the traveller's journey
> Over the sea-like, pathless, limitless waste of the desert.

The leaves of this plant not only assume an almost vertical position, but by a singular twisting of their blades, bring themselves into a position which truly justifies the name of Compass-plant. The lobes of each pinnate-parted leaf, extending like fingers on either side of the midrib, point due north and south, with an accuracy as unerring as that of the magnetic needle; while the broad surfaces face east and west. If, however, one of these plants be removed from its somewhat arid surroundings and replanted in a moist and shady spot, where there is no danger from over-transpiration, the phenomenon will presently cease. The leaves will untwist, and the plant will no longer be a Compass-plant, except in name.

The leaves of the Sea-reed (*Psamma arenaria*) exhibit a special structure in view of this same purpose—the prevention of excessive loss of water. The plant in question is the Common Matweed of our sand-hills, whose spreading fibrous roots are so useful in binding together the shifting sands on the coasts of Norfolk and Holland. It has been noted that "on wet days the leaves open longitudinally, so that their inner surface is freely exposed to the air, and the stomata which are situated there may not have their functions restricted ; in dry weather, on the contrary, the leaves are rolled up so that the leaf almost forms a tube, the outer surface of which is hard and quite impervious to water." The mechanism by which this is effected is to be found in certain cells, which form longitudinal rows at the base of the furrows on the under surface of the leaves, and which are very sensitive to moisture. In damp weather the cells increase in turgidity by absorption of water, and the leaf opens.

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* This is also a protection from the injurious effect on the chlorophyll corpuscles of the intense sunlight.

In concluding these observations on the dangers to plants from excessive heat, and the means provided by Nature to counteract those dangers, one is naturally led to the opposite side of the subject, and the question arises, If too much heat be injurious to a plant, may not, under contrary circumstances, *too great loss of heat* be injurious too ? Moreover, if the all-wise Mother has devised means for protecting growing plants from the one evil, may she not also have devised means for protecting them from the other ?

To both questions an affirmative answer may be given. Loss of heat has no less to be provided against than excessive transpiration—the damp and chilly nights must be taken into account quite as carefully as the dry and sunny days ; for growth goes on in the plant more rapidly in some cases by night than by day, and if it were systematically deprived of heat during the hours of darkness, it would soon languish and die. Now the means which Nature has devised for protecting growing plants from loss of heat are beautifully simple. What is known as the "*sleep*" *of plants*—in other words, the nocturnal drooping and folding of leaves and flowers—comprehends the chief of those means, and we shall here confine our remarks to this well-known phenomenon.

If you have ever sauntered through a garden by night, and examined, lantern in hand, the dew-drenched vegetation, you will have stumbled upon some curious discoveries. It is easy to imagine the surprise evoked during such an excursion. As you pause before one of the well-ordered beds, and look down at the familiar plants, you involuntarily ask yourself, What has become of the flowers ? A few, indeed, are still plainly visible ; but there are others that you miss, nor do you realise what has become of them until, on closer examination, you discover that some are closed, and others are hanging down their heads so that only their green collar (the calyces) meet the eye ;

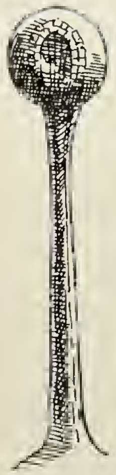


Fig. 258.—Glandular tentacles of Sundew.

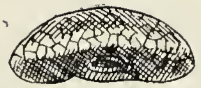


Fig. 259.—Sessile gland of Common Hop.

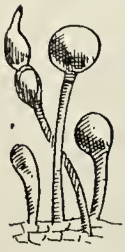


Fig. 260.—Glandular hairs of Snapdragon.

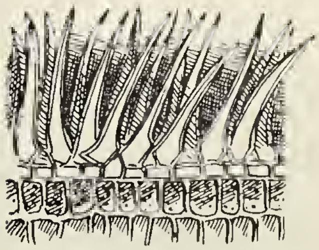


Fig. 261.—Simple unicellular hairs on a species of *Brassica.*

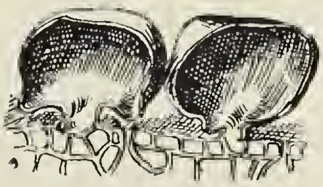


Fig. 268.—Portion of the flinty covering of a South African succulent plant.

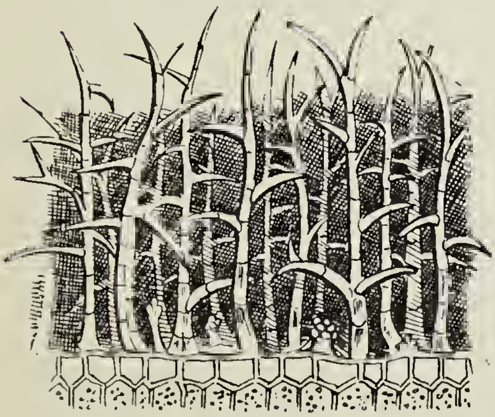


Fig. 264.—Branched hairs of *Nicandra anomala.*

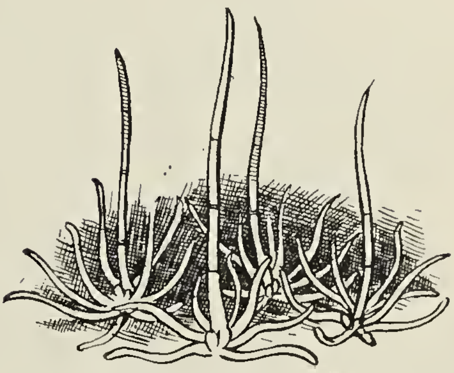


Fig. 263.—Tufted hairs of *Marrubium creticum.*

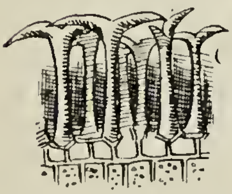


Fig. 262.—Forked hairs of Whitlow Grass.

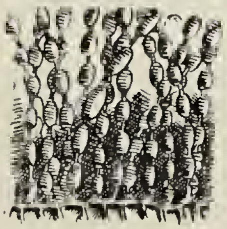


Fig. 265. — Muriform hairs of Marvel of Peru.

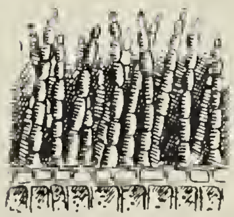


Fig. 266.—Muriform hairs of Virginian Spiderwort.

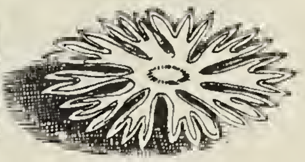


Fig. 267.—Stellate hair of *Alyssum spinosum.*

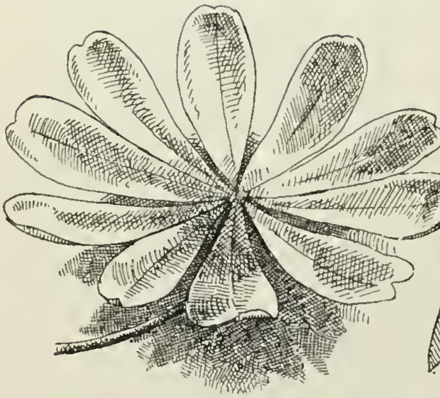


Fig. 269.—Day portion of Lupine.

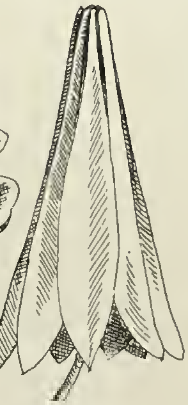


Fig. 270.—Night portion of same.

while others, again, have skilfully concealed themselves behind their own foliage leaves.

The leaves, too, appear to be wonderfully changed. "We are all a-noddin', nid-nid-noddin'," seems to be their drowsy language. The *Tropæolums* no longer confront the vault of heaven with their green shields, which hang listless at their sides; the Lupines have folded up their digitate leaves like umbrellas (figs. 269, 270); and on every hand the foliage seems heavy with slumber.

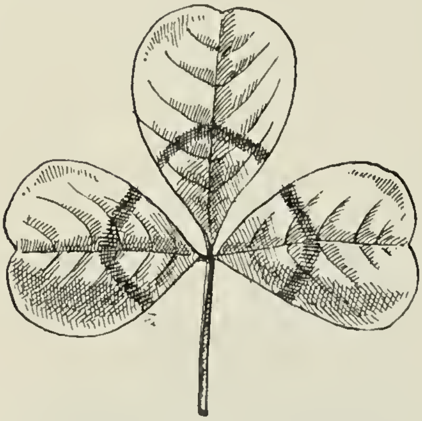


Fig. 271—Leaf of Clover expanded.

It may be cruel to unsettle so pleasing a fancy, but the phenomenon described, and which is popularly known as the sleep of plants, is simply a part of Nature's plan for guarding her vegetable protégés against excessive loss of heat. The "sleep" position of leaves is, in fact, a protective arrangement. By folding themselves together and assuming, as far as possible, a vertical position, radiation is materially checked, and thus the plants undergo no serious fall of temperature during the night. We must not be misled by this popular term "sleep" into supposing that the nutritive processes of the plant are suspended at this time. "The drooping position assumed by the leaflets of *Oxalis* is simply protective; there is no correlation between the assumption of the drooping position and the temporary loss of the power of assimilation. Preparations made at night from the leaves of *Oxalis* when in the drooping nyctitropic position show a normally active power of assimilation, and the same is the case with leaflets of *Mimosa*. The movements performed in assuming

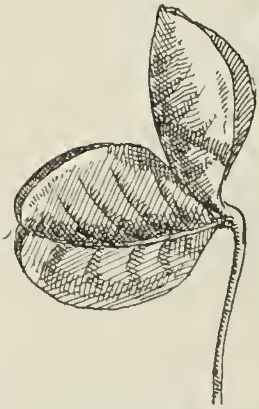


Fig. 272. — Leaf of Clover drowsy.

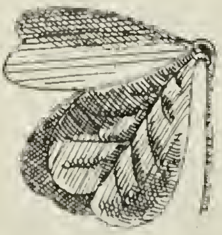


Fig. 273.—Leaf of Clover asleep.

the nocturnal nyctitropic position of certain "sleep" plants are not accompanied by any corresponding internal changes or alterations in the power of assimilation. In this respect the sleep of plants is more external and apparent than internal and real" (A. J. Ewart, B.Sc., in *Journ. Linn. Soc.* [Botany], vol. xxxi., 1896).

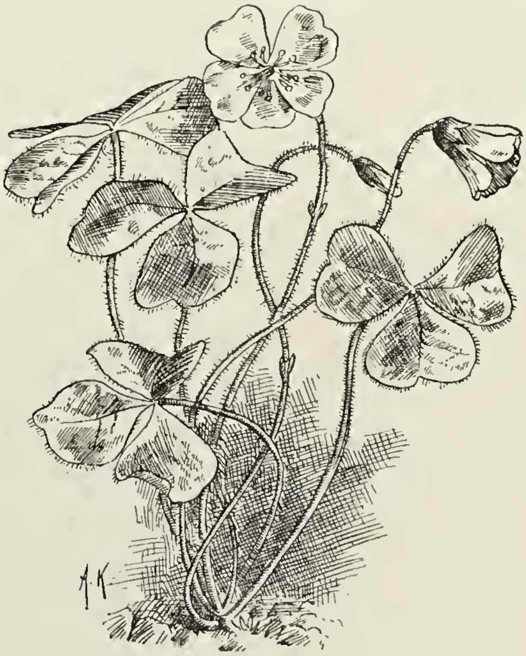


Fig. 274.—Day position of the Common Wood-sorrel.

Plants of the great Leguminous order, to which the Acacias, Mimosas, Peas, and Trefoils belong, exhibit the phenomenon of which we are treating in a very striking manner. The Wood-sorrels (*Oxalis Acetosella*, *corniculata*, and *stricta*), also, are extremely sensitive to changes of temperature, folding up their leaves even in the daytime if rain threatens (figs. 274, 275), while a blow from a stick will cause them to shrink together with affecting suddenness. Sensitiveness is carried to an extreme in a tropical species of this genus, *Oxalis sensitiva*, concerning which it is affirmed that even the disturbances of the air caused by the approach of man are sufficient to induce the phenomenon, the petioles relaxing and the pinnate leaflets falling together like the leaves of a book. This is also said to be the case with several of the Mimosas; but the two species which are most common in English stove-houses (*M. pudica*, fig. 276, 277, and *M. sensitiva*), though collapsing readily at the slightest touch, certainly do not exhibit such extreme sensibility in this country. The Mimosas have received poetic treatment from more than one distinguished poet. Erasmus Darwin says :—

Weak with nice sense the chaste Mimosa stands,
From each rude touch withdraws her timid hands;
Oft as light clouds o'erpass the summer glade,
Alarmed she trembles at the moving shade;

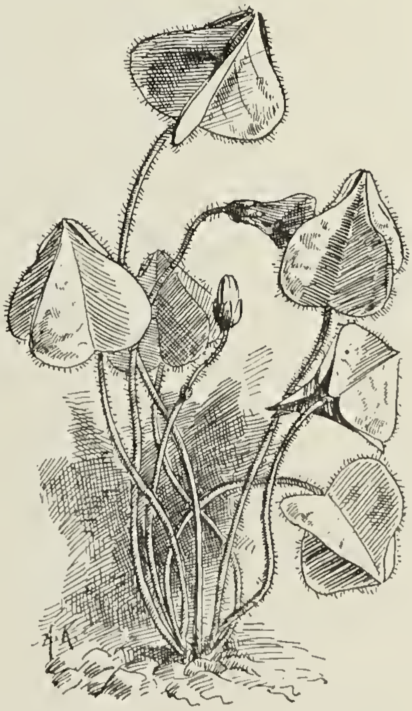


Fig. 275.—Night position of same.

And feels, alive through all her tender form,
The whispered murmurs of the gathering storm;
Shuts her sweet eyelids to approaching night,
And hails with freshened charms the rising light.

The movements of so-called sensitive plants are probably in part due to a peculiar modification of certain of their leaf-cells, which—in the Mimosas, at least—are so constructed that delicate threads of protoplasm pass through their walls and maintain a connection with the living matter of adjoining cells. Thus the effects of a touch on one part of a leaf may be transmitted all over it; and if, as is not unlikely, these perforated cells are distributed through the stem and branches as well as the leaves, the effects spoken of may be carried to every part of the plant.

The drooping of the leaf-stalk (which, as in the leaf of *Mimosa pudica* shown in figs. 276, 277, may alter its angle with the stem from ninety to thirty degrees) is caused by a beautiful piece of mechanism. At the base of the leaf-stalk there is a little cushion-like swelling, called the *pulvinus* (the Latin word for "cushion"), which contains a woody centre surrounded by parenchymatous cells, rich in water. When one of the pinnate leaflets is touched, the effect is transmitted to the pulvinus by the threads of protoplasm, with the result that the water passes from the cells on the lower to those on the upper side, causing the former to pass from a distended into a flabby state. They thus become temporarily unfit to support the leaf-stalk, which in consequence falls of its own weight. By and by the water gains its original distribution, and then the leaf-stalk resumes its horizontal position.

The celebrated Telegraph-plant (*Desmodium gyrans*, see Plate I.) is even more interesting than the Mimosas. It is an East Indian plant with violet flowers and trifoliate leaves, and the latter are in motion night and day. In bright sunshine the two lateral leaflets jerk up and down, and from side to side, in a remarkable manner, while the large terminal leaflet goes through similar though less perceptible movements (fig. 278). Should these movements be artificially checked for a while, the leaf will start again with increased velocity directly the retarding influence is removed. During darkness the terminal leaflet assumes the perpendicular position which has been already shown to be characteristic of "sleeping" leaves.

The trembling movement of the leaves of the Aspen (*Populus tremula*) has supplied many figurative allusions to prose-writers and poets, and the phenomenon deserves a passing notice. The quivering is due to the elasticity of the long flattened foot-stalks; and Mr. Colbourn, of Hobart, suggests that the rapid movement in the air enables the leaf

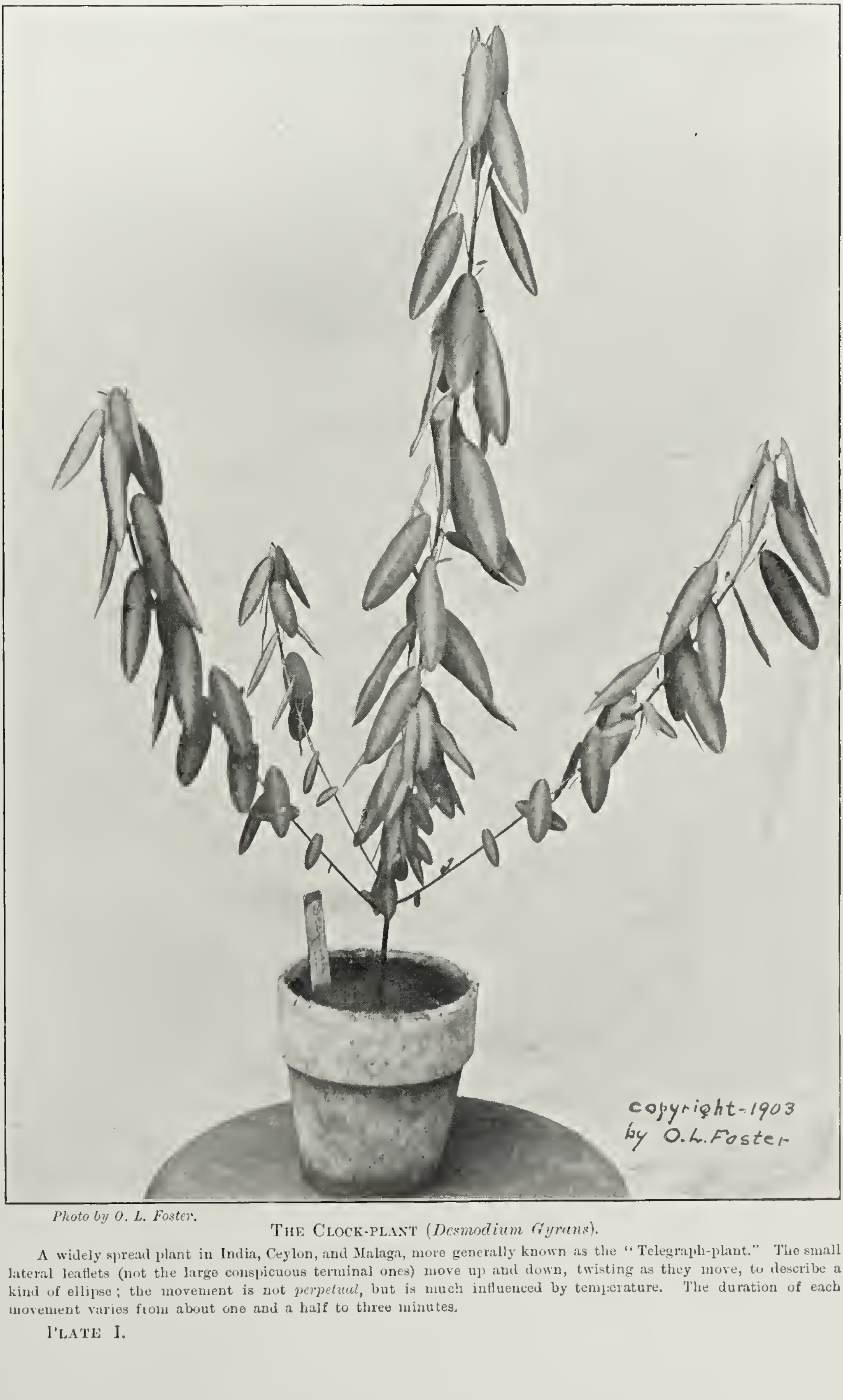


Photo by O. L. Foster.

THE CLOCK-PLANT (*Desmodium Gyrans*).

A widely spread plant in India, Ceylon, and Malaga, more generally known as the "Telegraph-plant." The small lateral leaflets (not the large conspicuous terminal ones) move up and down, twisting as they move, to describe a kind of ellipse; the movement is not *perpetual*, but is much influenced by temperature. The duration of each movement varies from about one and a half to three minutes.

PLATE I.

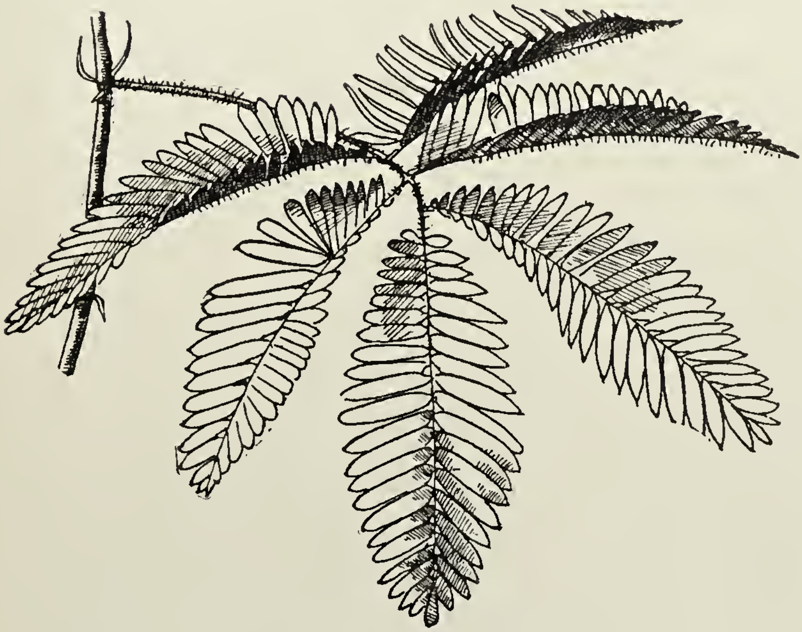


Fig. 276.—Day position of leaf of Sensitive-plant (*Mimosa pudica*).

to throw off the excess of moisture which collects on it in the damp situations of the tree. Kerner, however, regards the motion as an arrangement for protecting the flat broad leaves against crushing. He further remarks that the elasticity is due to the development of bast-strands in the leaf-stalks.

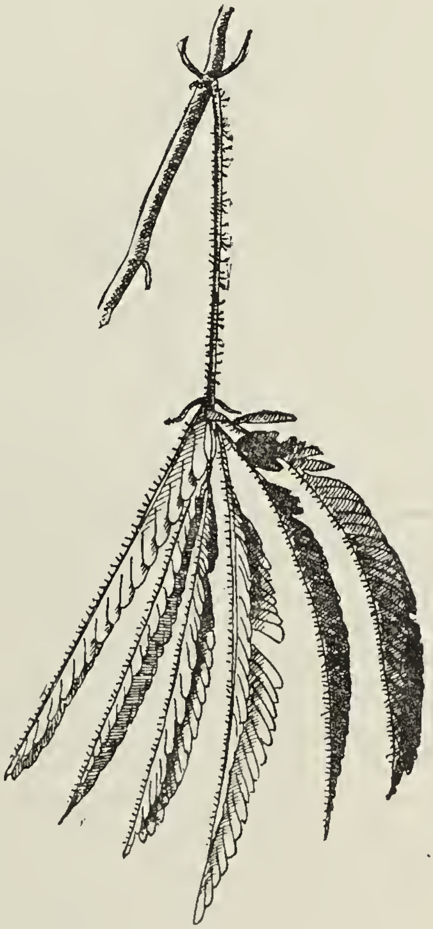


Fig. 277.—Night position of same.

We have now considered a few of the dangers to which the green leaves of plants are exposed, but the subject would be very imperfectly treated were no mention made of a danger of another kind. This form of danger belongs to the animate rather than the inanimate world—to "wild beasts and beasts of the field and creeping things" rather than to heat and cold and other such phenomena and forces. Innumerable animals feed upon the green tissues of plants, and find in a vegetarian diet their only sustenance; indeed, if Nature had not provided special contrivances to keep off these devourers, it is next to certain that whole families of plants would long since have vanished from the face of the earth. A few of these contrivances have been incidentally referred to in former chapters. When speaking of the sap of plants, we showed that the milky juice of the Common Lettuce (*Lactuca sativa*) protected the plant from the depredations of ants and other leaf-eating insects; and on a later occasion we saw that the thorns or spines in such plants as the Blackthorn (*Prunus spinosa*), Spiny Restharrow (*Ononis spinosa*), Spurges (*Euphorbia*), etc., render acceptable service by keeping off browsing cattle and herbivorous wild animals. But the subject was only lightly touched, and—from the nature of the connections in which it was introduced—many of these protective contrivances were not alluded to at all.

For example, no mention was made of *prickles*. Prickles are another kind of thorn. They are not, like spines, branches which have degenerated, for they spring from the epidermis or cortex of a plant member, and contain no fibro-vascular bundles; while spines, it will be remembered, are traversed by those bundles, which connect them with the vascular system of the stem and root. Good examples of prickles are offered by the Dog-rose (*Rosa canina*) and the Holly (*Ilex*), to name no other plants. In the former they occur on the petioles and branches; in the latter they spring from the margins of the leaves.

Fig. 278.—Telegraph-plant.

Plants of a prickly nature seldom develop those structures on leaves and branches which are out of reach of grazing animals. The Common Holly (*Ilex Aquifolium*), the bristly dentate leaves of which form a characteristic feature of shrubby specimens of the plant, produces only unarmed leaves, with entire margins on its upper branches, when it attains to the dignity and dimensions of a tree. Indeed, the gradations from the prickly to the unarmed forms of leaves in the plant named are so numerous and marked, that the species has been separated into varieties to distinguish them. Compare, for example, a leaf of Henderson's Holly (*Ilex A. Hendersoni*, fig. 279) with one of the Donington variety (*Ilex A. Doningtonensis*, fig. 280), and both with a leaf of the Hedgehog Holly (*Ilex A. ferox*, fig. 281); which latter has prickles not only at the margin, but also on the upper surface. Its popular name is, indeed, exceedingly appropriate—so, too, is its Latin appellative—*ferox*, "savage." Several plants of the large genus *Solanum*, to which

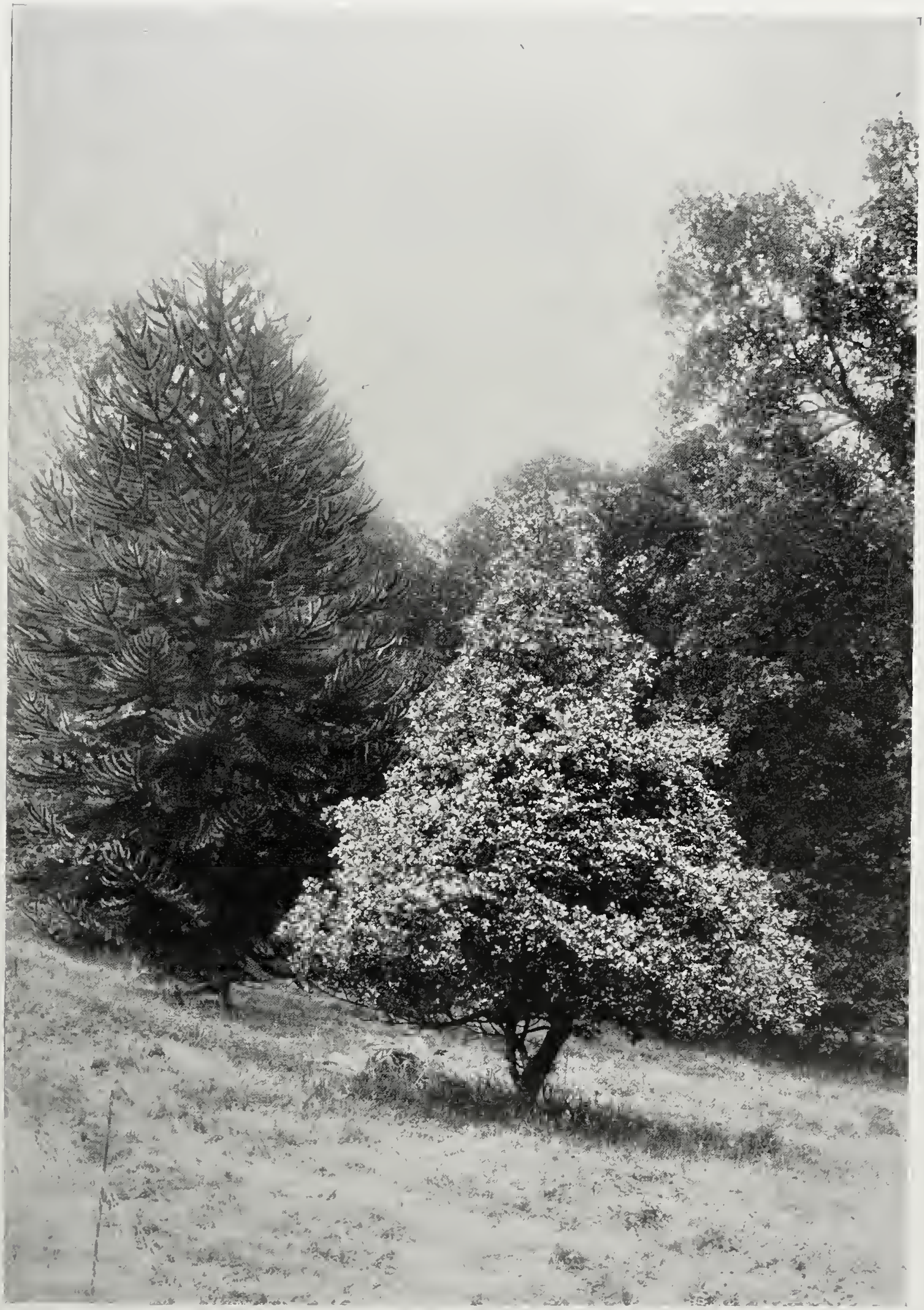


Photo by C. C. Hedges, Hexham.

TWO WELL-KNOWN LAWN AND SHRUBBERY TREES.

The tree to the left is the interesting Conifer, *Araucaria imbricata* (Chili Pine), popularly known as the Monkey Puzzle. In the centre is a golden-leaved variety of the Common Holly (*Ilex Aquifolium*). Both trees offer striking examples of the defensive armature of plants.

PLATE XXV.

the Potato-plant and Woody Nightshade belong (*e.g.*, *S. Fontanesianum*, *Jacquini*, and *maroniense*), have spiny erections on both sides of the leaf. They are borne upon the midrib and veins, and make the plants extremely awkward things to handle.

Many other protective arrangements more or less similar to those described occur readily to the mind; as, for instance, the sharp, strong, needle-shaped (*acicular*) leaves of many Grasses; the formidable thorny terminations of the leaves of the Agaves, and the spine-bordered lobes of leaves like the Thistle (*Carduus*) and *Acanthus*. It has been asserted that in the Southern Alps sheep will frequently return from pasture with their nostrils cut and bleeding, and the shepherds know at once that the cause of the mischief is a species of stiff-leaved Grass, *Festuca alpestris*, which they seek to destroy by burning. In some instances, Grasses which cause discomfort to grazing animals will be dealt with by the animals themselves, who seize them low down with their teeth and tear them from the ground. Kerner saw thousands of tufts of the Mat-grass (*Nardus stricta*), which had been rooted up by oxen, lying dried and bleached by the sun on some meadows in the Tyrolese Stubaithal.

More formidable than any of the protective weapons yet mentioned are the *barbed bristles* which surround the buds on many of the *Opuntias*. Each of these is a sort of compound fish-hook in miniature, and woe to the unwary animal who pushes his nose against the smallest bunch of them! The little hooks enter the tender flesh, and cause intolerable itching, which is often succeeded by painful and, it may be, dangerous inflammation. The tormenting bristles are easily driven deeper, but the backward-pointing barbs tear the flesh unmercifully when any attempt is made to withdraw them. One species, *Opuntia Ficus-indica*, better known as the Prickly Pear, is abundantly naturalised in the Mediterranean area, where it forms impenetrable fences (see p. 222). Another species, *Opuntia ferox*, is said by Schleiden to be especially remarkable because of the strength and size of its defensive thorns. "Among the hairs and smaller spines," he says, "arise very long and thick spines, in different form and number, which give the best characters for the determination of the species. In some, these are so hard and strong that they even lame the wild asses which incautiously wound themselves when kicking off the spines to reach the means to still their thirst. In *Opuntia Tuna*, which is the kind most frequently used for hedges, they are so large that even the buffaloes are killed by the inflammation following from these spines running into their breasts. It was this species, also, which was planted in a triple row as a boundary line between the English and French in the island of St. Christopher." Fig. 282 represents a flowering branch of *Opuntia multiflora*.

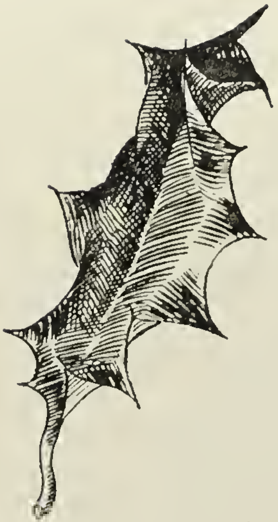


Fig. 279.—Leaf of Holly.

No account of the protective armature of green leaves would be complete without a reference to *stinging hairs*. The mention of these very remarkable structures brings to mind the Common Nettle (*Urtica dioica*)—a weed that is known to every child. Let us take a peep through the microscope at one of its stinging hairs, and try to realise what takes place when any rash meddler with the plant gets stung. Our picture (fig. 283) represents a hair in section. It consists of a long, tapering single cell, rising from a cushion-like base, and widening at the apex into a little knob, which is bent somewhat out of the perpendicular. At the point where this bend takes place the cell-wall is extremely thin—so thin that a very slight touch suffices to break off the knob. When, therefore, such a touch is given, the mischief is done, and the acrid irritating fluid contained in the cell escapes at the point of rupture and enters the tiny wound which the vitreous apex of the knob has made. The fluid consists of formic acid and a sort of unorganised ferment or enzyme, the latter being thought to be the more poisonous property of the two. It may be added that the break takes place obliquely (a consequence of the bend above described), so that the broken end resembles the poison-fang of a serpent—to which, indeed, it has sometimes been compared.

A brush from the leaf of any of the British Nettles (*Urtica dioica*, *urens*, and *pilulifera*) is doubtless a light matter, but to be stung by some of the Asiatic species is a very different thing. The great Shrubby Nettle (*Urtica crenulata*) of Northern India, for

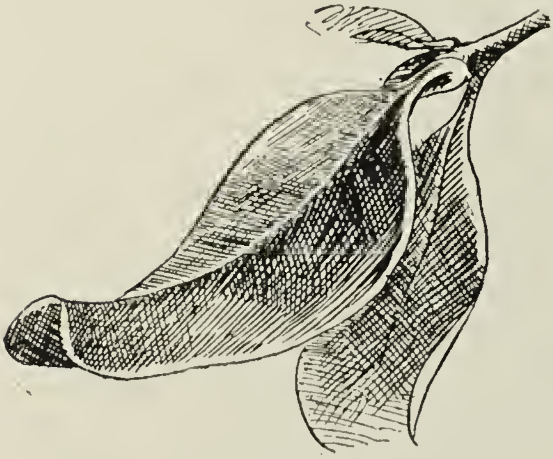


Fig. 280.—A variety of the Common Holly.

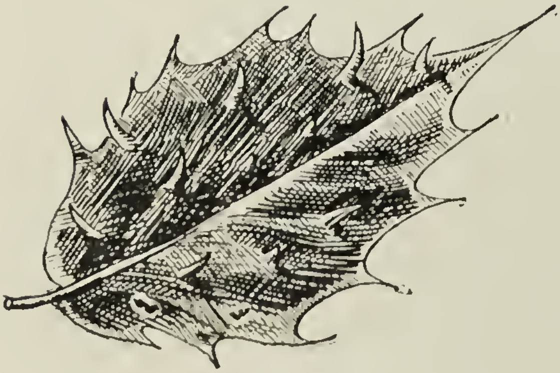


Fig. 281.—A variety of the Common Holly.

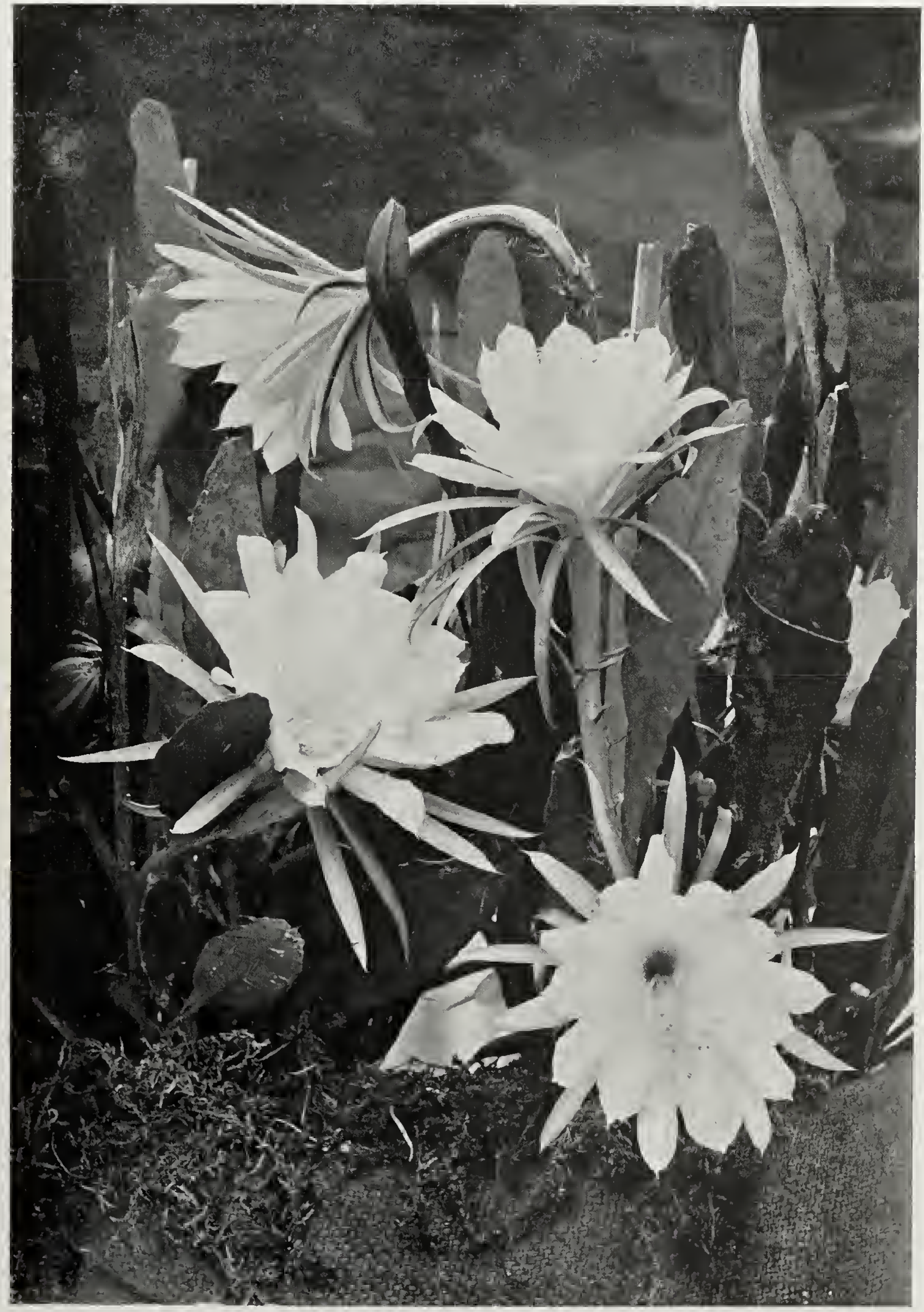


Photo by Walter Rossiter, Bath.

A species of *Phyllocactus* from Central America.

Plate XXXI.

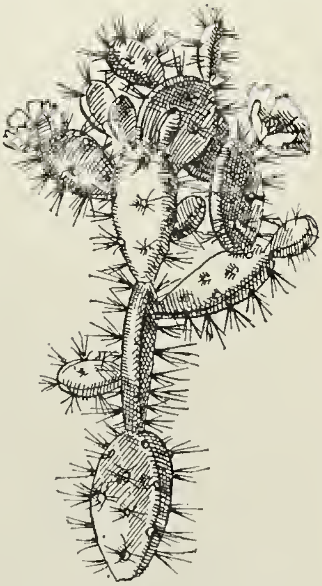


Fig. 282.—*Opuntia multiflora.*

instance, is a nettle to beware of. "This plant," says Sir Joseph Hooker in his *Himalayan Journals*, "called 'mealum-ma,' attains fifteen feet in height; it has broad glossy leaves, and though apparently without stings, is held in so great dread that I had difficulty in getting help to cut it down. I gathered many specimens without allowing any part to touch my skin; still, the scentless effluvium was so powerful that mucous matter poured from my eyes and nose all the rest of the afternoon, in such abundance that I had to hold my head over a basin for an hour. The sting is very virulent, producing inflammation; and to punish a child with 'mealum-ma' is the severest Lepcha threat." The writer explains in a footnote that the hairs are microscopically small, and that they only sting violently during the autumn. M. Leschenault, a French botanist who had the misfortune to be stung by the "mealum-ma" at this particular season, while gathering one of the leaves for his herbarium, describes the symptoms that followed as anything but pleasant. At first he felt only a slight pricking which he wholly disregarded; but the pain gradually increased, and at the end of an hour it had become excruciating. The parts affected—the first three fingers of his left hand—felt as though they were being rubbed with a hot iron. Before long the pain had spread up the arm to the arm-pit; and within five hours of being stung the torture was increased tenfold by an ominous contraction of the muscles of the jaw, which made him fear an attack of lockjaw. However, the latter symptoms passed away towards evening, and from that time the pain continued to decrease, though upwards of nine days elapsed before it entirely left him.

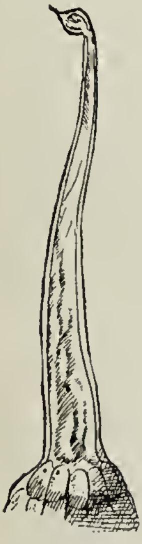
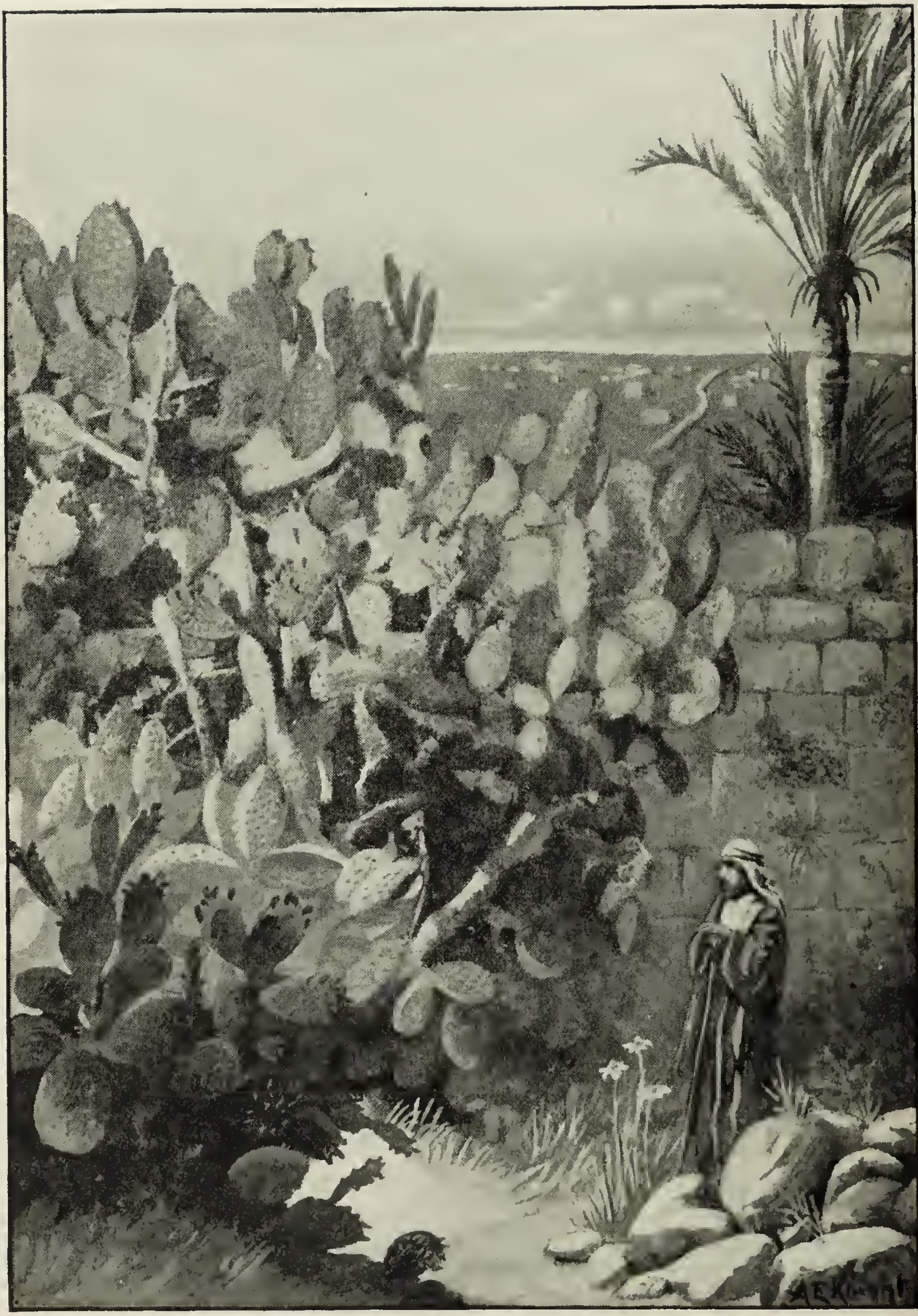


Fig. 283.—Stinging hair of Nettle.

That the inferior animals are sensitive to the stings of plants no less than man, and therefore that stinging hairs may be a real protection from grazing animals, is illustrated by the fact mentioned by Baillon, that the natives of Java rub buffaloes with a species of Nettle (*Urtica stimulans*) in order to excite them to fight with tigers. On the other hand, these vegetable fangs are innocuous to certain leaf-eating insects, which feed upon them with impunity; indeed, it is well known that the leaves of our British Nettles, which are all furnished with stinging hairs, form the only food of



From a drawing by Alfred E. Knight.

Hedge of Prickly Pear Cactus.

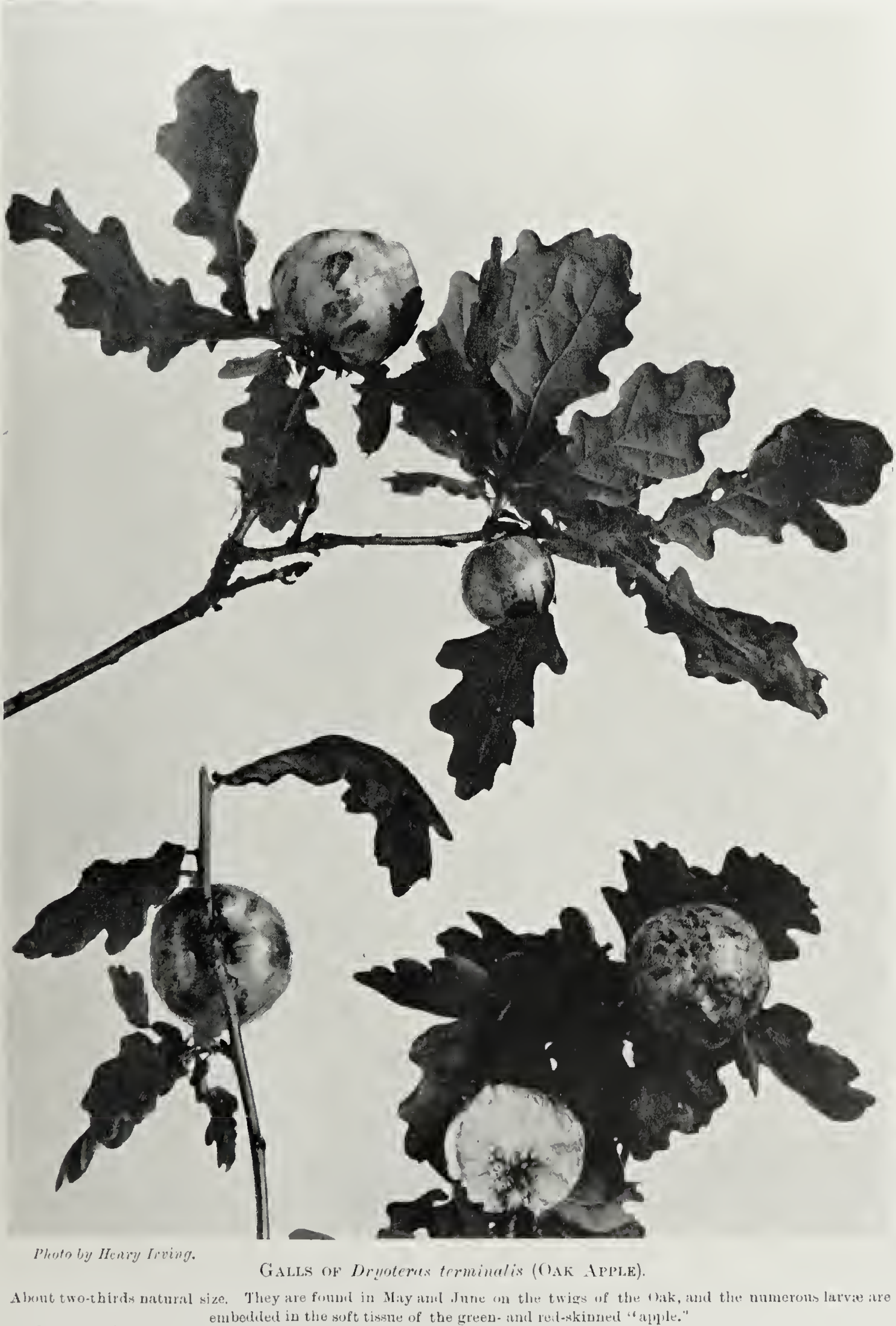


Photo by Henry Irving.

GALLS OF *Dryoteras terminalis* (OAK APPLE).

About two-thirds natural size. They are found in May and June on the twigs of the Oak, and the numerous larvæ are embedded in the soft tissue of the green- and red-skinned "apple."

PLATE XI.

the caterpillars of three of our most beautiful butterflies—namely *Vanessa Atalanta*, *V. io*, and *V. urticæ*. But this fact affords us a very striking object-lesson on the way in which an offensive or merely defensive development in one organism may lead to very considerable adaptation in some other organism that may be seriously affected by it. The three caterpillars named have developed protecting spines which keep the stinging hairs of the Nettle from contact with their tender skins. Their relative, *P. Cardui*, which feeds on Thistles, is similarly protected. It is remarkable that, so far as we have read, botanical writers have failed to note that hairs similar to those of the Nettle, but in a far less highly developed condition, are found on the leaves and young twigs of the Common Elm (*Ulmus campestris*). They are abundant along the midrib on the lower surface, and though they have nothing like the malignity of the Nettle, they cause a considerable amount of irritation to the hands and wrists of those who touch the leaves. The Elm sends up numerous suckers, and all down the bole it throws out new shoots, which would probably be browsed off but for the presence of these hairs. The Elm belongs to the same natural order (*Urticaceæ*) as the Nettle.

It may not be generally known that the singular growths called *galls*, so often to be seen on the leaves and branches of Flowering Plants, are due to insects. Formerly they were held to be entirely of a vegetable nature, and the insects found in them were thought to have been spontaneously generated there. Many species of Cynips lay their eggs in the parts named, plunging their exceedingly delicate ovipositors into the soft tissues, and thereby set up local irritation, which induces a responsive action of the protoplasm, and galls are produced. In some cases, however, the development of the gall does not commence until after the egg is hatched. No tree, probably, furnishes so great a variety of these growths as the Oak (*Quercus*), on which upwards of one hundred and fifty species have been observed, the well-known oak-apple being one of them. It is produced by the punctures of *Andricus terminalis*. Two specimens of Oak-gall often to be met with are produced by an insect named *Spathegaster baccarum*. Fig. 284 represents a leaf of a species of Lime (*Tilia platyphyllos*) with little conical excrescences or nail-galls, the work of a microscopic species of Phytoptus (*P. tilæ*), whose portrait you will notice just above the leaf. The green, mossy-looking growths called *bedeguars*, or Robin Redbreast's Pincushion, so common on branches of the Rose, are also of insect origin (fig. 286). The gall-fly (*Rhodites rosea*) deposits its eggs in the shoot-bud, which presently swells up and begins to put out what should be in the natural course three leaves; but embryo leaves have so little parenchyma between their veins that they fall into threads and thus give the mossy appearance to the galls. On cutting open one of the bedeguars the larvæ of the insect will be found in the centre (fig. 286). In all these cases it appears that only the cells of the meristem can give rise to the galls.

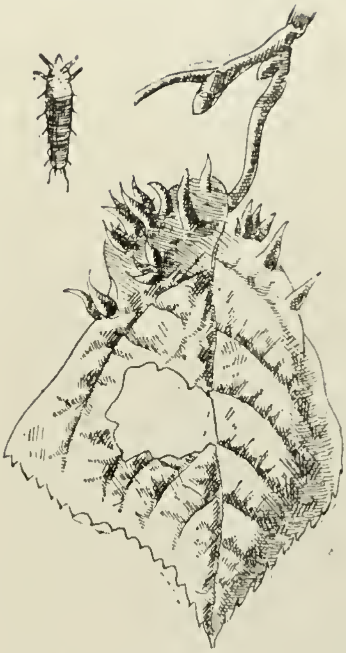


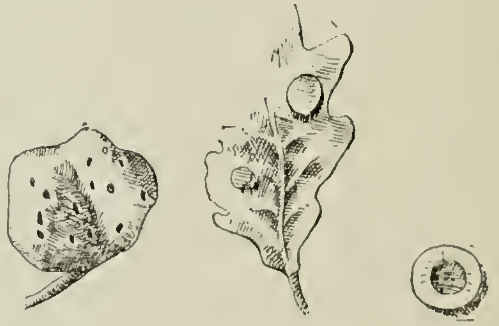
Fig. 284.—Leaf of Lime with nail-galls, and gall-mite of same.

What is known as *fasciation*, or the fusing together of parts of a plant which are normally distinct, as in the triple flower of Fuchsia shown in fig. 287, is likewise (at least, in a large number of instances) due to gall-mites. Many of the singular metamorphoses of plant organs, too—floral leaves which are changed into foliage leaves, petals which become stamens, etc., etc.—are probably attributable to the same exciting cause—a subject of which we shall have more to say when speaking of the Flower.

Erasmus Darwin, in his now little-read yet singularly interesting poem, *The Botanic Garden*, calls upon his "sylphs" to—

> wound the wormy galls
> With pigmy spears, or crush the venomed balls;

but there is really no necessity for such sanguinary and remorseless measures. Growths of this kind *as a rule* do very little harm to the plants on which they are found. Nay, in some instances they have a positive economic value. The galls of commerce are chiefly those which occur on *Quercus infectoria*, and the best of them come from Aleppo and Smyrna. They yield a fine black colour with any of the salts of iron, and are largely used in the manufacture of writing-ink. Perhaps the most dreaded of gall-producing insects is the grape-louse (*Phylloxera vastatrix*), which pierces with its proboscis the young leaves and roots of the European Vine (*Vitis vinifera*), and thereby causes the growths referred to. The poet's "sylphs" might carry on their pigmy warfare here to advantage! The galls, by drawing away nourishment from the roots (in which they are ably assisted by the insects themselves), starve and weaken those delicate organs, and at last destroy the plant. In the short space of three



Oak-apple formed by a gall-mite. Portion of the Oak-leaf with two galls. One of the galls, under side.

Fig. 285.

years the yield of wine in the department of Vaucluse (Southern France) was reduced to about one-tenth of the former amount simply through the ravages of this tiny aphis.

We have now touched upon all the more important facts connected with the forms, structure, and functions of foliage leaves, and with the means provided by Nature for their protection and preservation. A few remarks on the *decay and fall of the leaf* may fitly conclude the subject.

One of the first external signs of incipient decay in green leaves is the fading of their freshness. The green becomes dull, and gradually assumes a yellow, brown, or ruddy tinge, due to varying degrees of oxidation of the chlorophyll contained in the cells. It will be remembered that chlorophyll, though a single pigment, is easily decomposed, and the products of its decomposition are xanthophyll, a bright yellow, and erythrophyll, a red pigment ; and experiments have shown that there is an absence of the latter in yellow autumn leaves. The fact appears to be that, prior to its fall, the leaf is practically emptied of its useful contents ; every bit of serviceable protoplasm being drawn away to other organs of the plant, and what remains—the shining yellow granules which give their colour to the fallen leaf—is simply the useless residue. The darker autumn tints, on the other hand, are due to the second-named pigment, erythrophyll, which may be made to assume the most various colours—purple, red, violet, etc.—according to the quantity and nature of the acids contained in the cell-sap. When red erythrophyll occurs with xanthophyll, an orange colour is the result.

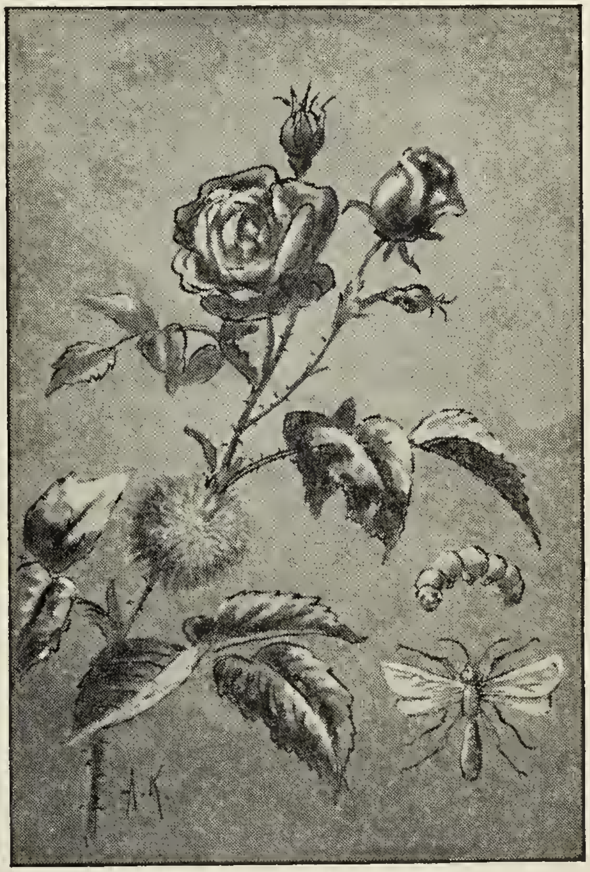


Fig. 286.—Flowering branch of a Rose surrounded by a bedeguar gall. The gall-fly and grub of same are shown in the corner of drawing.

The *fall of the leaf*—by which we now mean its actual severance from the parent plant—is not primarily nor necessarily due to external forces. Wind and frost may, and do, perform their part, but long

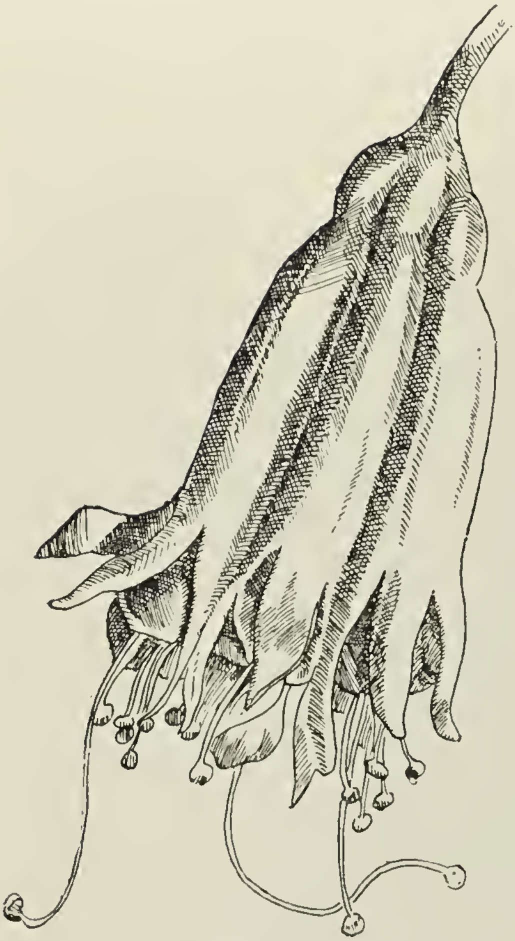


Fig. 287.—Monster flower of a Fuschia.

before the leaf has attained its full growth and vigour the busy protoplasts have been weaving a layer of cells, which shall infallibly ensure the work of disarticulation. These cells, botanically known as the *layer of separation*, are formed at the base of the leaf-stalk, and run at right angles to the older and displaced cells, so that they divide the leaf from its branch or stem, somewhat in the same way (to borrow Dr. Maxwell Masters's excellent simile) as the drop-curtain of a theatre divides the stage from the body of the house. The new cells are thin-walled and parenchymatous, and being modified and weakened at a later stage by organic acids, a very slight cause will effect a splitting. Wind and frost are doubtless the chief of these auxiliary causes, but a slight shower of rain is often sufficient, or the leaf may fall of its own weight.

There is a further fact to be noticed. The layer of separation not only secures the fall of the leaf, it remains as a shield or covering when that event has taken place. Thus the plant does not suffer from the effects of an open wound. An examination of the scars on any branch denuded of its leaves in the manner described will show how beautifully and efficiently this part of the work is done (fig. 288). No surgeon could perform an amputation more cleanly; and there is this evident superiority in Nature's surgery, that when she lops off a limb there is no bleeding afterwards. In using the expression "Nature's surgery," we trust that we shall not be misunderstood. By Nature we do not mean a mere force or evolutionary influence, but the Power that operates behind

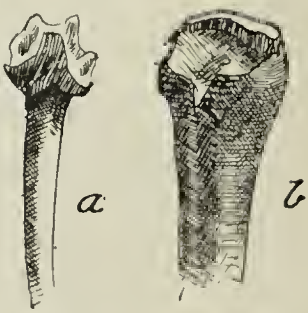


Fig. 288.—Parts of leaf of Horse-chestnut. (*a*) The ends to which leaflets were attached. (*b*) The end that was attached to branch.

Nature—a Power evidently possessing intelligence and foreknowledge. That the protoplasm of a plant is obeying certain natural laws when it weaves its layer of cells across the leaf-stalk of a plant, no less than when it builds up the complicated structure of the leaf itself, we do not for one moment deny, but an intelligent Power must be behind those laws, directing and controlling them, and that Power, as we thankfully believe, is God. The great facts of biology reveal the folly of all atheistic pretensions: Materialism is confounded in the presence of a palpitating bioplast.

The Fall of the Leaf.

CHAPTER X

FLORAL FORMS AND THEIR RELATIONS TO INSECTS

> To me the meanest flower that blows does bring
> Thoughts that do often lie too deep for tears.
>
> WORDSWORTH.

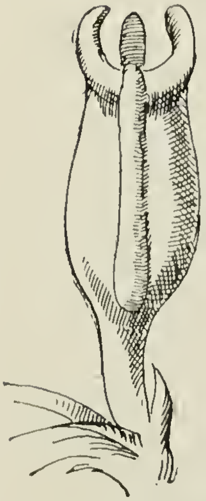


Fig. 290.—Bud of a Lily.

As there is a good deal of ground to be covered in this chapter, we will not waste time on the threshold. Our subject is the Flower—in many respects the most important, as certainly it is the most interesting, of the subjects of which Botany treats. The Flower contains the organs of reproduction, a fact which accounts for its pre-eminent importance; while the manner in which those organs discharge their appointed functions—assisted often by the most unlikely agencies, as water, wind, and insects—gives to the study of the Flower an attractiveness all its own. Root, stem, and leaf are not without their fascinations, too, as we have sought show in earlier chapters, but the Flower is the part of the plant which rightfully commands the lion's share of interest.

As with the leaf, the beginning of the Flower is the bud. Flower-buds originate in much the same way as leaf-buds, and cannot be distinguished from the latter in their earlier stage. Like leaf-buds, too, they are formed either in the axils or at the ends of branches, and in accordance with those conditions

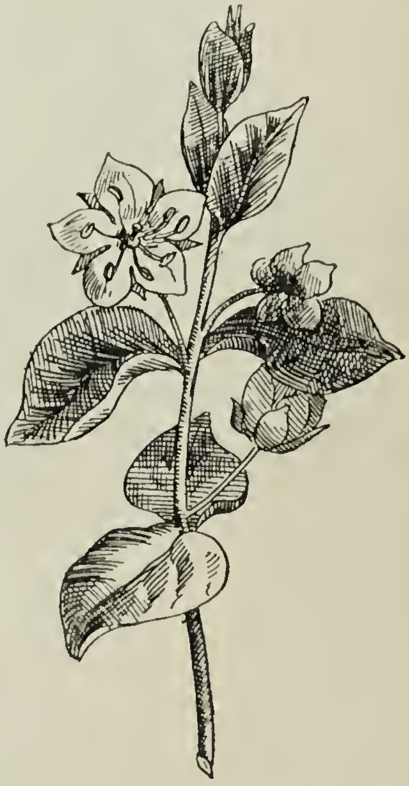


Fig. 291.—Solitary and axillary flowers of Creeping Loosestrife.

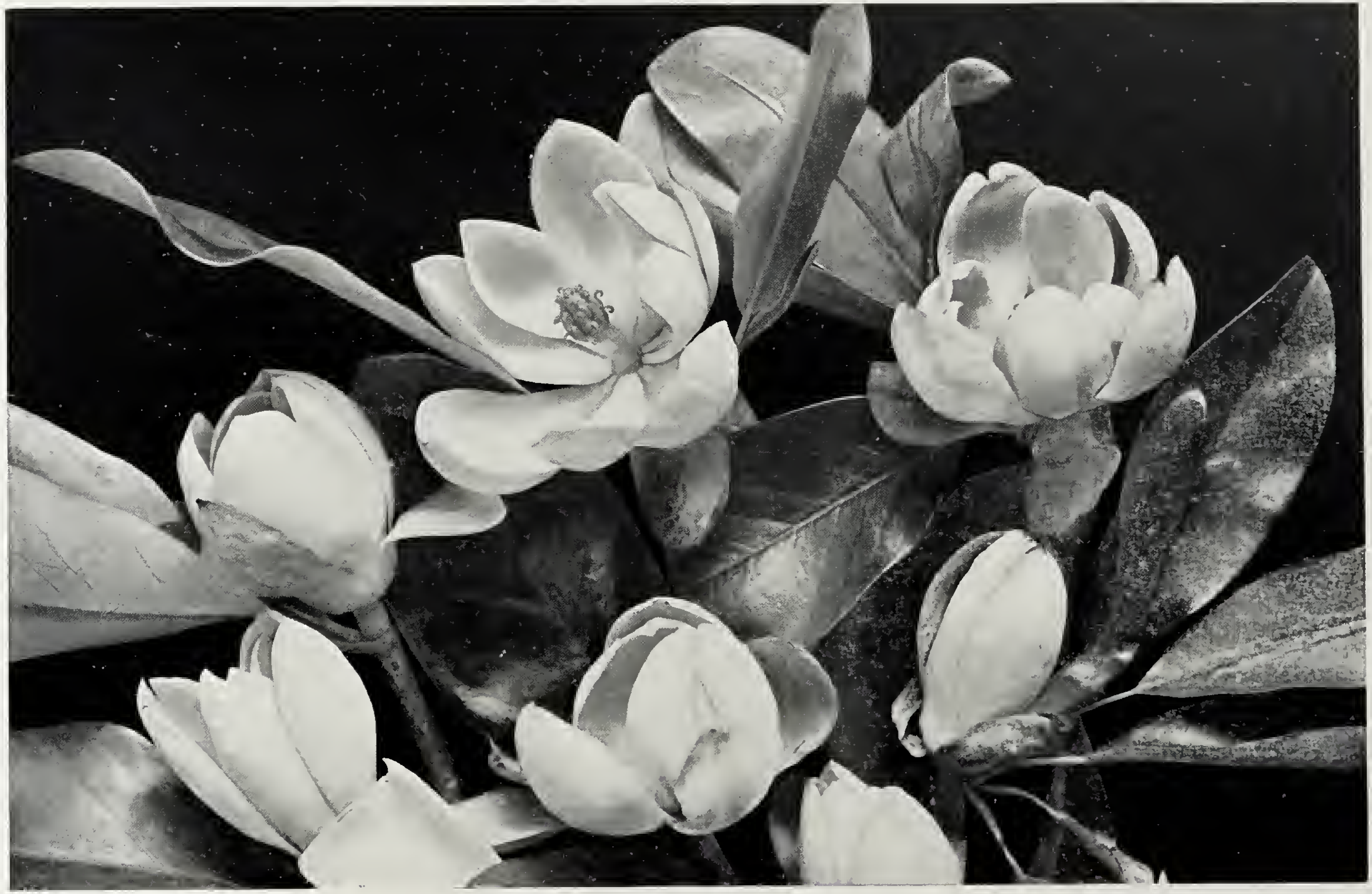


Photo by Henry Troth.

MAGNOLIA (*M. glauca*).

Showing the flower in successive stages of expansion.

PLATE VII.

Photoby Walter Rossiter, Bath.

Double Poppies, Varieties of *Papaver somniferum.*

Plate XXXIII.

are named respectively *axillary* and *terminal.*

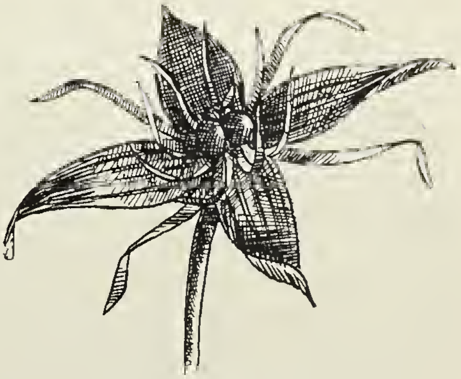


Fig. 292.—Solitary and terminal flower of Herb-paris.

The reader will probably recognise the little flower shown in fig. 291. It is the Moneywort or Creeping Loosestrife (*Lysimachia Nummularia*), an English wild-flower partial to ruins and damp woods, and a favourite rockery plant under cultivation. It offers a familiar example of a *solitary* and *axillary* flower. The Herb-paris (*P. quadrifolia*, fig. 292), bears solitary flowers, too, but they are *terminal*, not axillary. The Herb-paris is one of the most singular of our wild-flowers, and, like the Moneywort, delights in moist and shady woods.

But solitary flowers, whether axillary or terminal, are the exception rather than the rule. In by far the greater number of plants the bud unfolds into a branch system, consisting of several flowers, which are known collectively as the *inflorescence.* The Cowslip (*Primula veris*), Cherry (*Prunus Cerasus*), and Forget-me-not (*Myosotis palustris*) may serve as examples. What is popularly known as the "flower" of the Daisy (*Bellis perennis*) and Dandelion (*Taraxacum officinale*) is likewise an inflorescence; each of the so-called flowers being really a multitude of minute flowers (*florets*) crowded together on a single stem. We will consider the structure of one of these composite flowers later on.

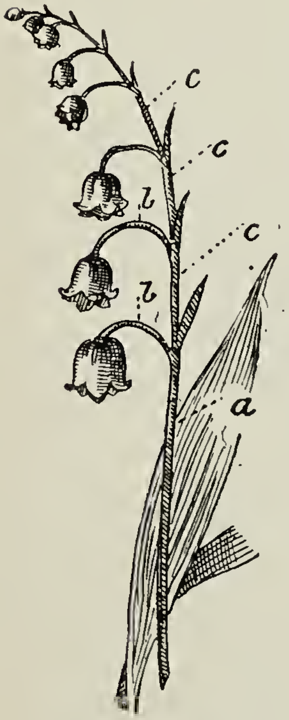


Fig. 293. — Flowering stem of Lily of the Valley. (*a*) Peduncle. (*b b*) Pedicels. (*c c c*) Rachis.

In describing a flower the presence or absence of a stalk should always be noted. Stalkless or *sessile* flowers are comparatively rare, but the flower-stems of stalked or *pedicellate* flowers may be so short as to be hardly perceptible. No more remarkable instance of a sessile flower could be named than that vegetable wonder, *Rafflesia Arnoldi*, of which some account was given in a former chapter; and if we place side by side with *Rafflesia* the stalked inflorescence of the celebrated *Lilium giganteum*, we have a contrast indeed. A flower-stem of one of these Lilies, cut from a living plant in the Sunningdale Nursery in July, 1879, is preserved in No. 1 Museum at Kew. The circumference of the pedicel is eleven and a half inches, its height thirteen feet! Truly a Brobdingnagian flower-stem.

A stalk which supports a solitary flower, or the primary stalk of an inflorescence, is called a *peduncle*; while the branches or secondary stalks are known as *pedicels*. The stalk of Herb-paris, one of the flowers that we were looking at a moment ago, is an example of a peduncle; so is the primary stalk of the Lily of the Valley (*Convallaria majalis*), while its slender branches, curving with the weight of the dainty little bells, are pedicels (fig. 293). The portion of the floral stem (peduncle) which, in this plant, bears the stalked flowers, is the *rachis*. *Rachis* is the Greek word for "spine," and besides being the term used in anatomical science for the vertebral column of animals, is used for many things which suggest a resemblance to the spine, as the shaft of a feather, the stalk of the frond in Ferns, the axis of a compound leaf, and (as we have just seen) the axis of an inflorescence.

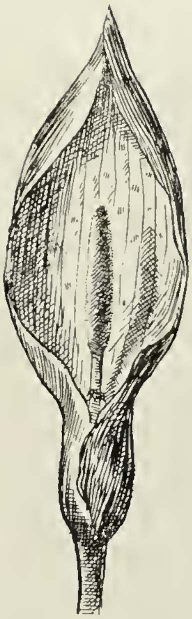


Fig. 294.—Cuckoo-pint (*Arum maculatum*).

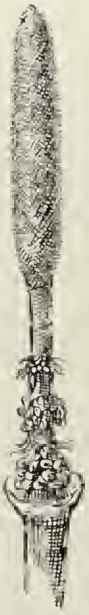


Fig. 295.—Spadix of Cuckoo-pint.

The Lily of the Valley is an extremely useful plant for an object-lesson. Who is not familiar with its pensile beauty? It is a favourite flower under cultivation, and one of the most sought after of wild-flowers. The plant needs some seeking, too, for it loves to hide from sight in shady glens, covering its nodding white bells with its large and glossy leaves.

> She nor affects
> The public walk, nor gaze of midday sun:
> She to no state or dignity aspires,
> But silent and alone puts on her suit
> And sheds a lasting perfume, but for which
> We had not known there was a thing so sweet
> Hid in the gloomy shade.

You perceive that the leafless peduncle springs directly from a subterranean stem or root-stock—a rhizome, to use the botanical term. On this account the inflorescence is called a *scape*, and the plant itself a *scapigerous herb*. The Primrose, Cowslip, and Oxlip (*Primula vulgaris*, *P. veris*, and *P. elatior*) also offer familiar examples of scapigerous herbs.

Notice, further, that the pedicels of the Lily of the Valley spring from the axils of what appear to be minute leaves—a fact of importance, as similar leaf-like forms are found on most branched inflorescences.

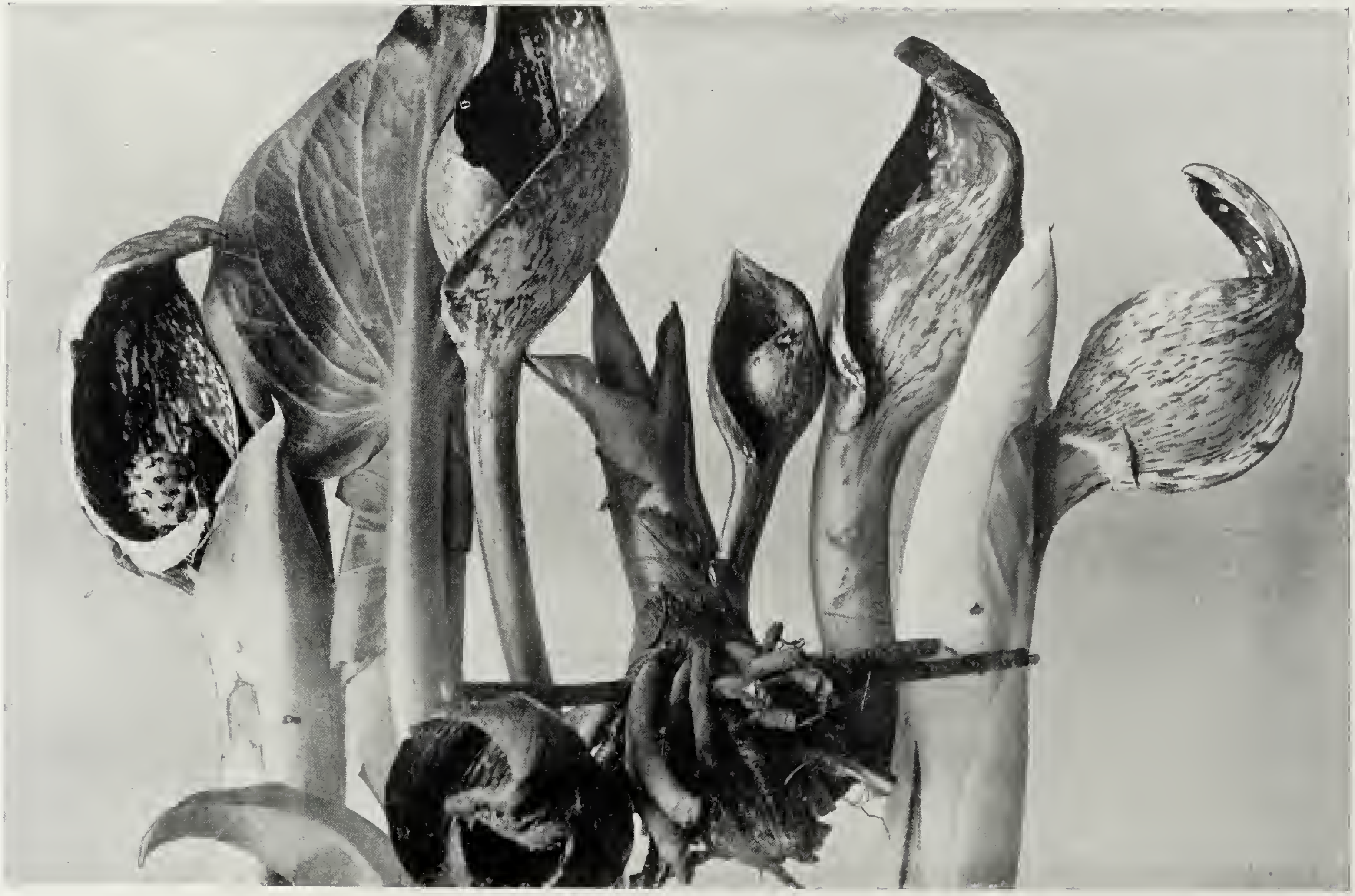


Photo by Henry Troth.

SKUNK CABBAGE (*Symplocarpus fœtidus*).

Interesting as showing an intermediate stage between the open spathe of *Calla palustris* and the closed prison of *Arum maculatum*.

PLATE XXII.

They are called *bracts*, from the Latin *bractea*, a thin plate of metal. Bracts are usually green, but in certain plants—as the Flowering Dogwood (*Cornus florida*) and the celebrated Edelweiss (*Leontopodium alpinum*)—they are white or coloured like the petals of flowers, and are then called *petaloid*. In *Poinsettia* they form the most showy portion of the inflorescence, the flowers themselves being small and inconspicuous. The names *bracteate* and *ebracteate* are applied to flowers according as they possess or do not possess these modified leaves.

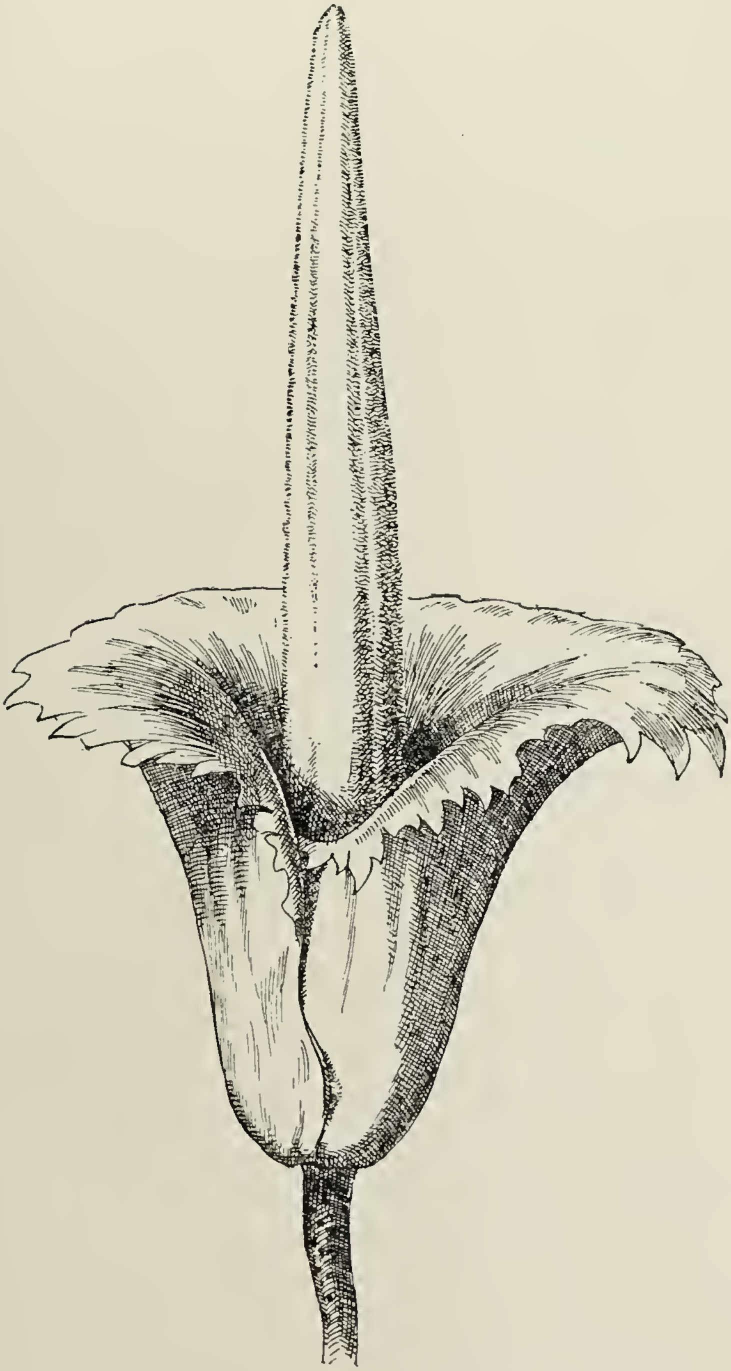


Fig. 296.—Giant Arum (*Amorphallus Titanum*).

Here is a flower that will be readily recognised (figs. 294, 295). No lover of green lanes and sunny meadows bordering banks can be a stranger to the Cuckoo-pint or Wake Robin (*Arum maculatum*), with its "ear-like spindling flowers," as Clare calls them, "betinged with yellowish, white, or purplish hue." But let us be clear as to what we are looking at. The figure does not represent a single flower, but an inflorescence, the

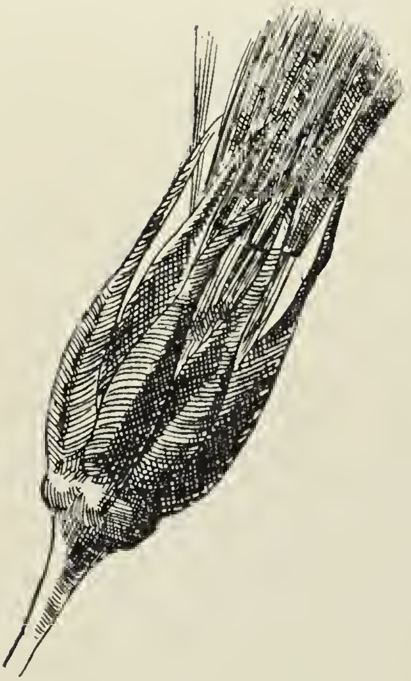


Fig. 297.—Involucre of Yellow Goatsbeard, closed.

numerous flowers of which are congregated round the narrow lower part of the club-like column or *spadix*, while the spotted enveloping case is simply a special kind of bract, known as a *spathe.* Any large spadix-ensheathing bract, indeed, is termed a spathe, and such leaves are quite distinct from the foliage leaves both in form and functions. The spathe of *Amorphallus Titanum*, an Aroid of Western Sumatra, measures nearly three feet in diameter, while its purple spadix attains a height of nearly six feet, and a single leaf has been known to cover an area of forty-five feet in circumference (fig. 296).

In a large number of plants the bracts are collected in a whorl around a cluster of flowers, and then we have what is called an *involucre.* Such an arrangement is often of great service to the densely packed florets, particularly during the night, when loss of heat by radiation is largely prevented by the closing of the involucres. The Yellow Goatsbeard (*Tragopogon pratensis*) and Dandelion (*Taraxacum officinale*) may serve for illustration (figs. 297, 298). Could any more perfect arrangement have been devised for protecting their clustering florets from sudden changes of temperature than these circles of stout little bracts? The Wood-anemone (*A. nemorosa*), whose white or delicate crimson petals open in April or May, has a whorl of three leaf-like involucral bracts at some distance below its single flowers. In the Limes (*Tilia*) the long bracts remain on the trees till the fruit is ripe, and fall with it (fig. 299). They serve the purpose of wings, and materially assist the wind in dispersing the seed. Whether the curious accrescent bracts of *Neuropeltis racemosa*, an Indian plant belonging to the Bindweed family (*Convolvulaceæ*), subserve a similar purpose, we are not in a position to say.

In the Grasses the outer scales of the spikelets are called *glumes*, the inner *pales* or *paleæ.* One of our common cereals may be

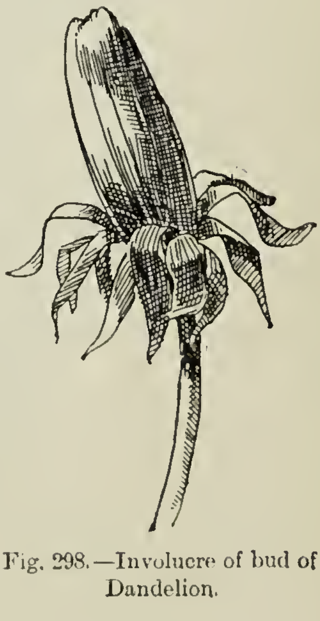


Fig. 298.—Involucre of bud of Dandelion.

taken as an example. Here (figs. 300, 301) is a branched inflorescence or *panicle* of the Common Oat (*Avena sativa*), consisting of a peduncle and pedicels, with a flower-containing spikelet at the end of each. To the right of the panicle one of the spikelets is shown separately, on a larger scale, the glumes or outer scales being lettered *gl.*, while the pales or inner scales are lettered *p.* The long bristle-like appendage with which one of these inner scales is furnished is known as the beard or *awn*.

All inflorescences resolve themselves naturally into two great divisions. When, as in the Pink (*Dianthus*), Buttercup (*Ranunculus*), Gentian (*Gentiana*), etc., a single flower ends the primary axis, which is thereby arrested in its growth and does not elongate, fresh flowers being produced from separate axes and expanding after the central flower, then we have what is known as a *definite* inflorescence. When, on the other hand, the flowers are produced laterally on the axis, which elongates and continues to produce flowers in regular succession from below upwards—as is the case, for instance, in the Snapdragon (*Antirrhinum*) and Wallflower (*Cheiranthus Cheiri*), then the inflorescence is said to be *indefinite*. Figs. 302-304 will illustrate the difference: figs. 302 and 303 represent definite inflorescences, the latter with numerous floral axes: the inflorescence on the right (fig. 304) is indefinite. The numerals indicate the order in which the flowers open.

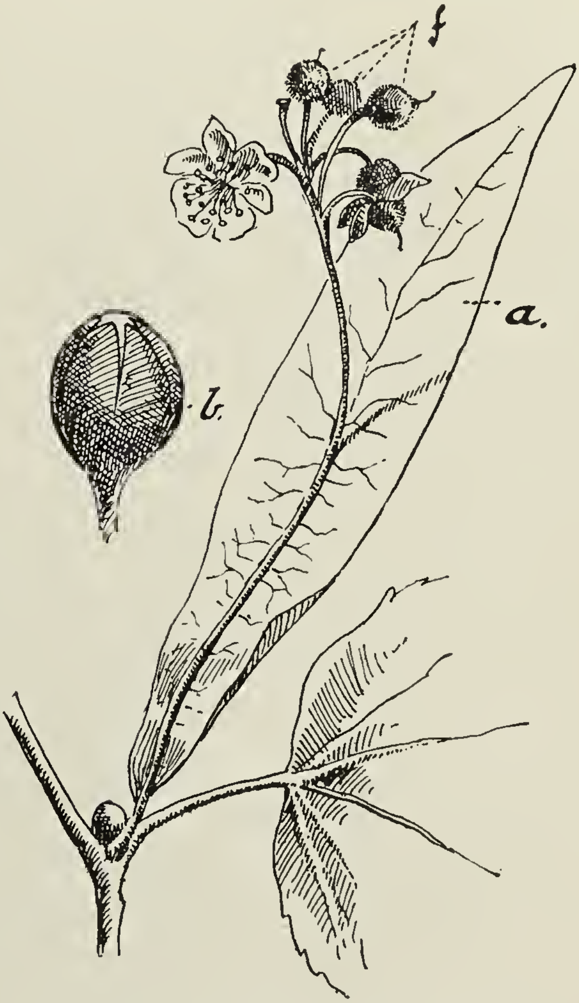


Fig. 299.—Inflorescence of the Lime. (*a*) Bract. (*f*) Fruits. (*b*) A bud (magnified).

There is no need to give a detailed account of the various kinds of inflorescence. They are pretty numerous, and have received names which Dominie Sampson would have loved to roll off his tongue. Under the head of definite inflorescences we have the *fascicle*, the

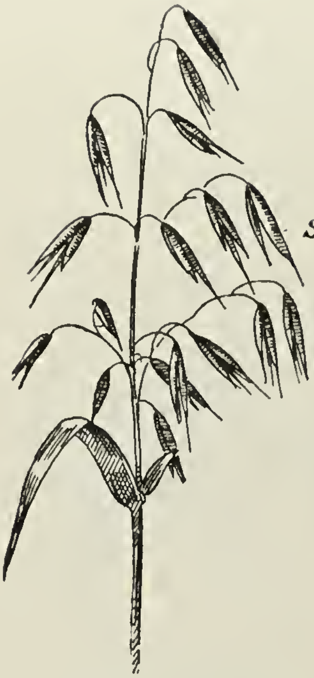


Fig. 300.—Branched inflorescence (panicle) of Oat. (s) Spikelets.

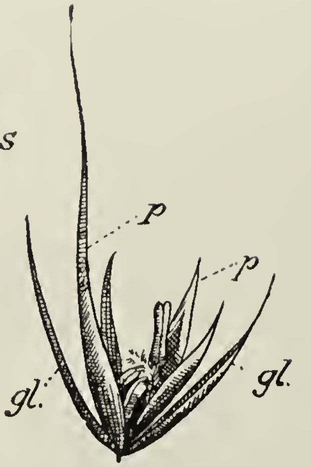


Fig. 301.—Detached spikelet of same. (gl) Glume. (p) Pales (one with a long arm).

glomerulus, the *verticillaster*, and five kinds of *cyme*—*spiked*, *panicled*, *corymbose*, *dichotomous*, and *scorpioid*, while the nomenclature of the various forms of indefinite inflorescence is even more extensive. Those with lengthened axes and sessile flowers, which form a sub-group under the common name of *spikes*, comprise the *catkin*, *spadix*, *strobile*, and *cone*; those with lengthened axes and stalked flowers, constituting a second sub-group under the name of *racemes*, comprise the *corymb*, *panicle*, and *thyrsus*. Then there are the forms with shortened axes and sessile flowers, the *anthodium* and *hypanthodium*, which may be bracketed under *capitula* to make a third group; and, lastly, we have the two kinds of *umbel*, *simple* and *compound*, both characterised by shortened axes and stalked flowers.

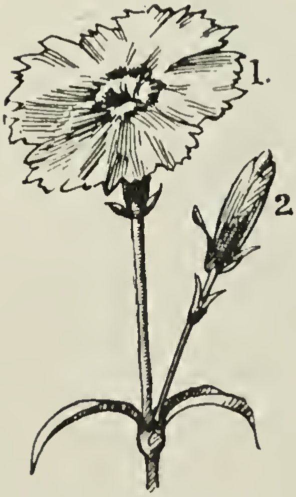


Fig. 302.—Definite inflorescence.

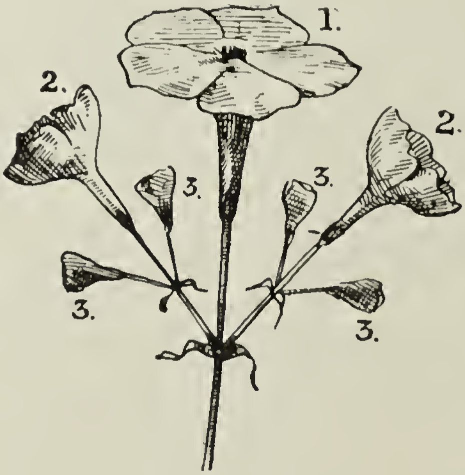


Fig. 303.—Definite inflorescence with numerous floral axes.

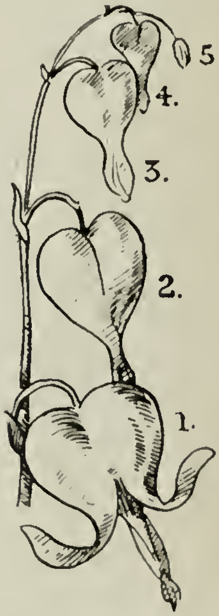


Fig. 304.—Indefinite inflorescence.

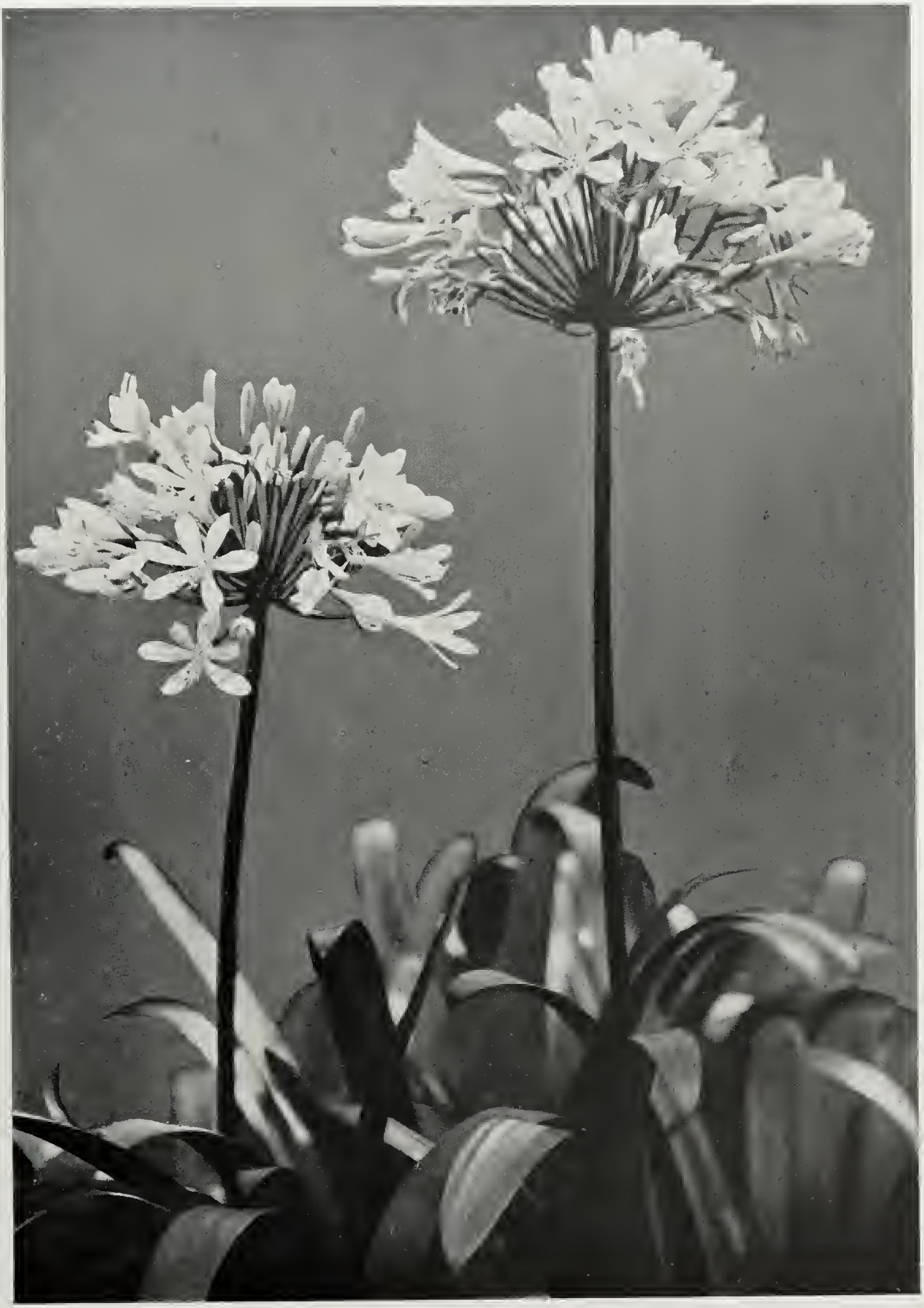


Photo by Walter Rossiter, Bath.

African Lily (*Agapanthus umbellatus*).

A Cape plant with umbellate heads of bright blue flowers. Common in England as a garden pot-plant.

Plate XXIX.

They may be tabulated thus, and the illustrations will help the memory :—

DEFINITE INFLORESCENCES (page 236).	INDEFINITE INFLORESCENCES (page 237).	
Fascicle (*b*)	*Spikes.* (Sessile flowers on lengthened axes.)	*Racemes.* (Stalked flowers on lengthened axes.)
Glomerulus (*k*)	Catkin (*a*)	Corymb (*f*)
	Spadix (*b*)	Panicle (*g*)
Verticillaster (*c*)	Strobile (*c*)	Thyrsus (*h*)
Spiked (*a*)	Cone (*d*)	
Panicled (*f*)		
Cyme Corymbose (*d*)	*Capitula.*	*Umbels.*
Dichotomous (*g*)	Anthodium (*k*)	Simple (*m*)
Scorpioid (*b*)	Hypanthodium (*l*)	Compound (*n*)

Many useful ends are brought about by the massing together of inflorescences, and not the least of these is the facilitating of insect visits to the plant. Small surfaces of colour are always rendered more conspicuous if placed close to one another; and there can be little doubt that bees and other winged insects, which are known to play an important part in the cross-fertilisation of plants, are attracted more readily to flowers which club together, so to speak, than to those which maintain a solitary existence. We offer this remark in passing, but the subject will be before us again by-and-by, when there will be opportunity for considering the facts more fully.

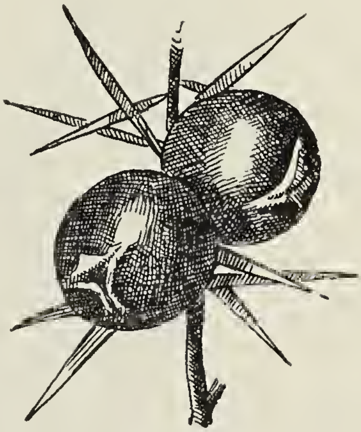
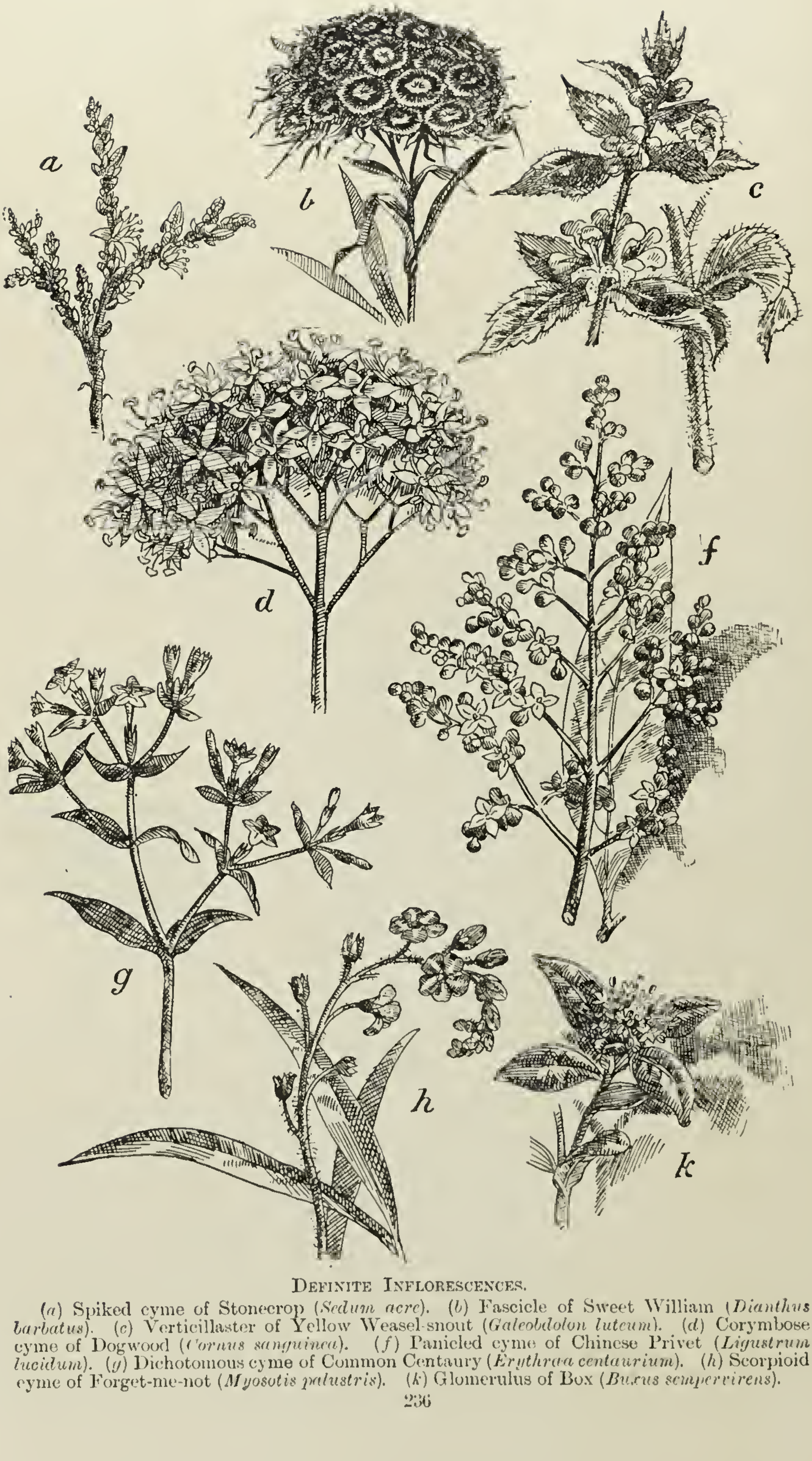


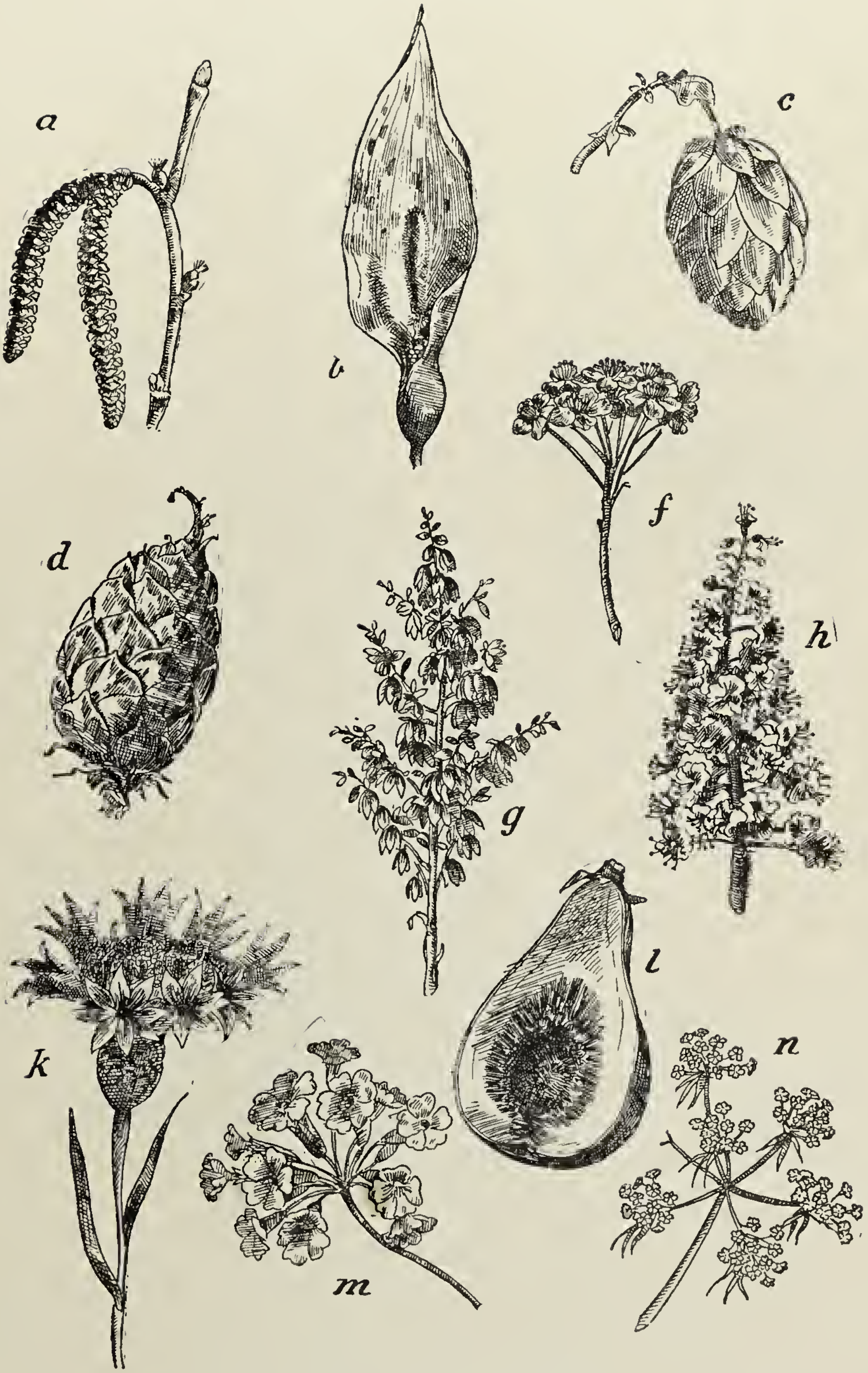
Fig. 305.—Berry-like cones of Juniper.

Thus far we have been considering flowers in clusters (*i.e.*, inflorescences) and little has been said of the flower as an individual; though this is really our main subject. What is a flower? Popularly the term is applied to the delicate and gaily coloured leaves or petals on a plant; but as many true flowers have no petals at all, it is easy to see that the popular conception is defective. Nor is it sufficiently exact to say that a flower is "that part of a plant which subserves the purpose of reproduction." Have we not already seen that leaves, roots, and stems may subserve a like purpose, being capable of producing buds which, whether they remain attached to the parent plant or are severed from it, are unquestionably new individuals? A far more satisfactory definition is furnished by Professor George Henslow, who calls the flower "a living machine for making seed



Definite Inflorescences.

(*a*) Spiked cyme of Stonecrop (*Sedum acre*). (*b*) Fascicle of Sweet William (*Dianthus barbatus*). (*c*) Verticillaster of Yellow Weasel-snout (*Galeobdolon luteum*). (*d*) Corymbose cyme of Dogwood (*Cornus sanguinea*). (*f*) Panicled cyme of Chinese Privet (*Ligustrum lucidum*). (*g*) Dichotomous cyme of Common Centaury (*Erythræa centaurium*). (*h*) Scorpioid cyme of Forget-me-not (*Myosotis palustris*). (*k*) Glomerulus of Box (*Buxus sempervirens*).



INDEFINITE INFLORESCENCES.

(*a*) Catkin of Hazel (*Corylus Avelana*). (*b*) Spathe of Cuckoo-pint (*Arum maculatum*) with club-shaped spadix surrounded by sessile flowers. (*c*) Strobilus of Hop (*Humulus Lupulus*). (*d*) Cone of European Larch (*Larix Europa*). (*f*) Corymb of Cherry (*Cerasus Mahalcb*). (*g*) Panicle of a Yucca. (*h*) Thyrsus of Horse-chestnut (*Æsculus Hippocastanum*). (*k*) Capitulum of Corn Bluebottle (*Centaurea cyanus*). (*l*) Hypanthodium of Common Fig (*Ficus carica*). (*m*) Umbel of Cowslip (*Primula veris*). (*n*) Compound umbel of Fool's Parsley (*Æthusa Cynapium*).

in order to reproduce the plant and so keep up a succession of its kind." Let us add that this mechanism is acted upon, *not* from *without*, like a loom, but from *within*, by the vital force which resides in the protoplasm.

If we take a simple flower—say a Buttercup—and examine it, we find that it consists of four distinct sets of parts, or *organs*. Starting from the outside (fig. 307) we have, first of all, a green *calyx* (*k*) composed of five leaf-ike organs or *sepals*; then the showy yellow leaves or *petals* (figs. 306 and 307, *c*), which are also five in number, and are called collectively the *corolla*; next a number of delicate and slender bodies—the *stamens* (*s*), each of which is furnished with a thread-like stalk—the *filament*, surmounted by a sort of double sac—the *anther*, which opens at the sides by two slits and contains in each of its cells or *lobes* a yellow powder—the *pollen* (fig. 310). The small part of the filament which runs up between the anther-cells is appropriately termed the *connective*. Lastly, in the very centre of the flower we come upon the fourth set of organs, consisting of a number of tiny green bodies—the *carpels*, seated upon a small elevated portion of the *receptacle*, and known collectively as the *pistil* (fig. 308). Looked at under a magnifying glass, each of these carpels is found to consist of a roundish part or *ovary*, which is gradually contracted above into a kind of short bent horn—the *style*, of which the tip or *stigma* is somewhat wider and more shiny than the rest. The ovary is hollow and contains the *ovule*, or precursor of the seed (fig. 309).

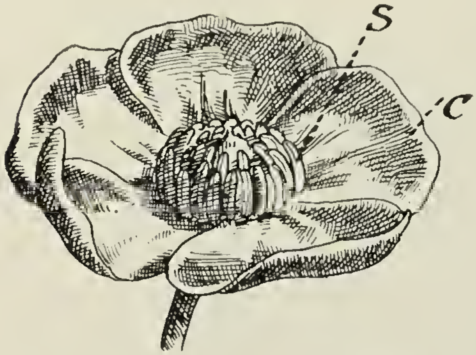


Fig. 306.—Flower of Creeping Buttercup (*Ranunculus repens*). (*c*) Corolla. (*s*) Stamens.

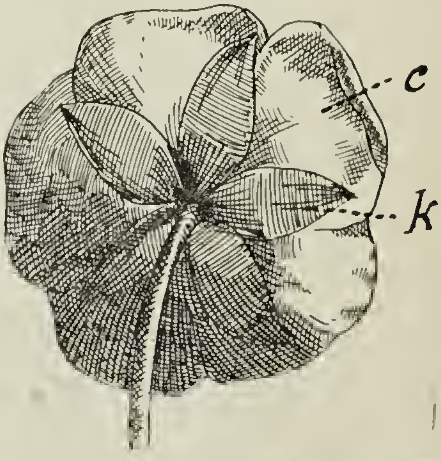


Fig. 307.—Back view of same. (*c*) Corolla. (*k*) Calyx.

Now the only parts of a flower which are absolutely necessary for the production of seeds are the stamen, or male organ, and the pistil, or female organ; and they are called on that account the *essential floral organs.* They stand in the same relation to the seed as parents to a child; in fact, they are the father and mother of the seed. The calyx or corolla are of altogether secondary importance, and are merely spoken of as the *floral envelopes.*

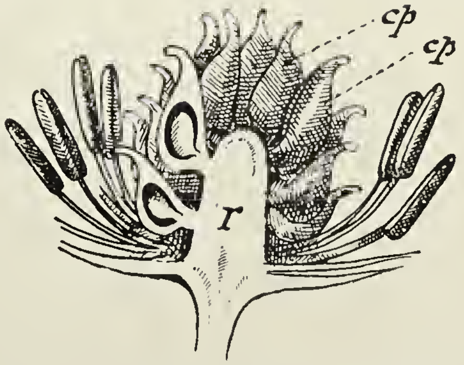


Fig. 308.—Vertical section of same. (*r*) Receptacle to which the carpels (*cp*) are attached. These form collectively the pistil, and, when ripe, the fruit.

Some writers have seen an analogy between a flowering plant and a bee-hive, and certainly a community of bees affords an instructive illustration if the search for resemblances be not pushed too far. Normally speaking, a hive contains three kinds of bees; first, the workers, which are of no sex, and usually number many thousands. They are the industrious members of the community, who provide the food and collect and give form to the raw material out of which the cells are constructed. Secondly, there are the males or drones, a less numerous company, though often amounting to several hundreds; and lastly there is the solitary female or queen-bee, upon whose fertility the perpetuation of the species depends.

So is it with the plant. The foliage leaves, which convert the raw food materials derived from the root, etc., into organic compounds, are the workers; the stamens, with their little sacs of meal-like pollen, answer to the males or drones; and the pistil, with its ovules, corresponds fairly well with the female or queen. When it is added that the pollen of the male organ is the fertilising agent of the female organ—the means by which the ovules are converted into matured and perfect seeds—it will be seen how close is the analogy.

It may be asked, In what way does the pollen of the male organ act upon the female organ? The process may be understood by reference to a section of the pistil of a well-known flower, the Snapdragon (*Antirrhinum majus*, fig. 311). Though differing very considerably in form from the pistil of the Buttercup which we were looking at a few moments ago, it resembles, in its main features, the individual carpels of that flower—indeed, like the carpels, it consists of an ovary (*a*), style (*b*), and stigma (*c*). The tiny round bodies shown on the surface of the stigma are grains of pollen, which have been conveyed thither from the anther-cells of the stamens *of another flower* by insect agency, and it is by means of those microscopic grains of yellow dust that the tiny unripe ovules in the swollen base of the pistil are to be fertilised, and thereby made capable

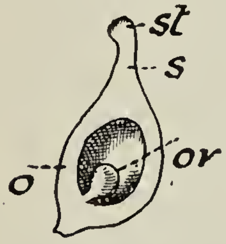


Fig. 309.—A carpel of same opened. (*st*) Stigma. (*s*) Style. (*o*) Ovary. (*ov*) Ovule.

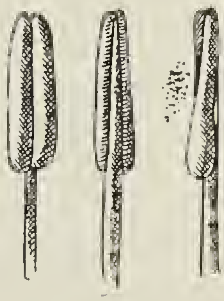


Fig. 310.—Stamens of same. Front, back, and side views.

of growing into perfect plant-producing seeds. This is effected in the following manner : On reaching the stigma, the pollen-grains, stimulated by a viscid secretion exuded from the stigmatic surface, presently put forth tubes, which force their way down the loose conducting tissue of the style (fig. 312) into the ovary, and so pass on to the ovules, where the definite act of impregnation takes place.

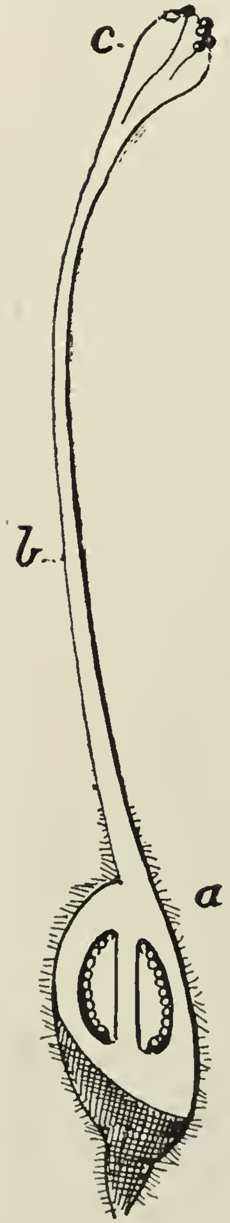


Fig. 311.—Longitudinal section of pistil of *Antirrhinum majus.* (*a*) Ovary. (*b*) Style. (*c*) Stigma.

It is important to get a clear grasp of what has been before us in this rapid sketch. The process that has been described is the same, in all essential particulars, as that which goes on in the great majority of flowering plants, and it is so simple as to be easily understood. The pollen may be conveyed to the stigma by other than insect agency, and the tubes may pursue a more winding course through the conducting tissue, but these are details, and the above description may be accepted as a fairly representative one. What actully takes place in the ovules when the pollen-tubes have found an entrance, will be explained farther on (Chap. XIII.) ; it is sufficient here to have directed attention to the fact itself. The growth of the tubes may be conveniently demonstrated with the pollen of the cultivated varieties of *Caladium*, all that is needed being to leave a few grains on a damp slide for five or six hours.

We have already seen that the beginning of the flower is, like the beginning of the leaf, the bud; and that a flower-bud and a foliage-bud are indistinguishable in the early stages of growth. The theory of the development of all parts of the flower from leaves was enunciated by the poet Goethe nearly a century ago; and though the announcement of his discovery was accompanied by a good deal of speculation which subsequent research has shown to be erroneous, his main position had much to recommend it, nor does it lack defenders even at the present day. Goethe taught that " the elementary floret expands into a leaf upon the stem, contracts to make the calyx, expands again to make the petal, to contract again into sexual organs, and expand for the last time into fruit "

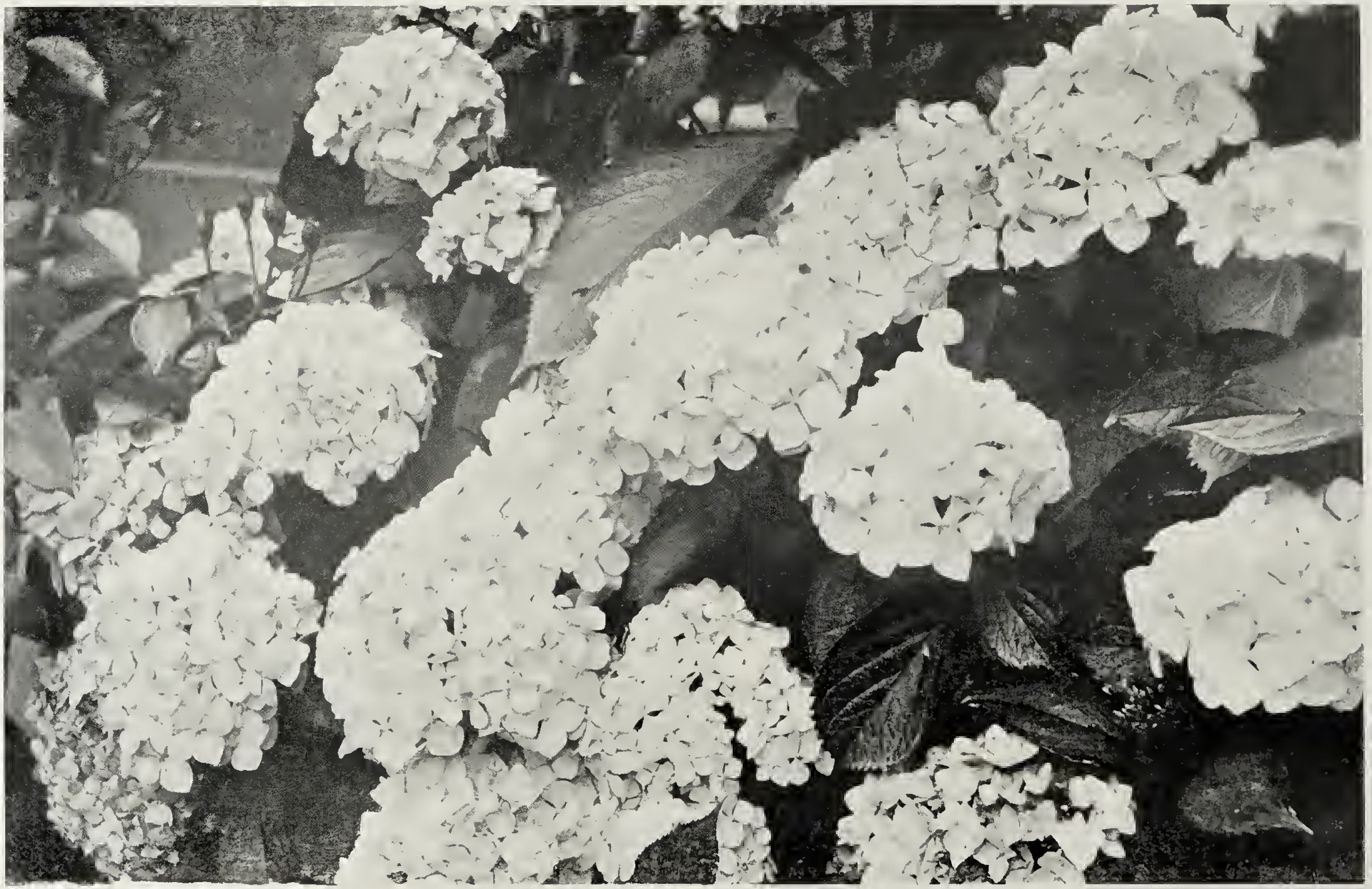


Photo by Walter Rossiter, Bath.

COMMON HYDRANGEA (*H. hortensis*).

The flowers grow in corymbs and are rarely fertile, the outer flowers being enlarged at the expense of the stamens.

PLATE XXXIV.

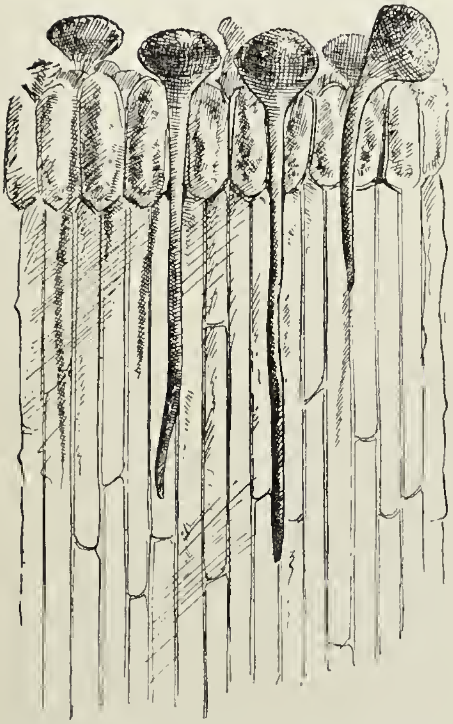


Fig. 312.—Portion of the stigma and style of *Antirrhinum majus*, with pollen-grains putting forth tubes.

On the other hand, there are physiologists of the first rank who hold the theory of the German poet in light esteem, and to whom the pronouncement that "every flower is simply a metamorphosed leaf-shoot" is a dangerous expression, implying that the flower has been developed in course of evolution from a leaf-shoot, for which, in their judgment, there is not sufficient evidence. We are disposed to concur in this view, and rather than yield allegiance too readily to Goethe's theory would say that there are flower-shoots and leaf-shoots, without attempting to derive one from the other.

Yet the tendency of the floral organs to relapse into the foliar form in certain abnormally developed flowers, at least confirms the idea that floral leaves and foliage leaves are homologous structures.

Most of us, doubtless, have met with flowers of the kind referred to—"monstrous" flowers, as they are called. In *Science Gossip* (1890) there is an interesting series of papers on the subject, by Dr. J. E. Taylor, with drawings of some of the more remarkable monstrosities. In one place we find an abnormal Knapweed (*Centaurea nigra*), of which some of the florets have become leaf-like; in another, a Daisy (*Bellis perennis*) has developed a true foliage leaf instead of a bract in the involucre. A third specimen (a flower of the Enchanter's Nightshade—*Circæa lutetiana*) appears with a portion of its stigma transformed into the anther of a stamen, and a stamen assuming the character of a petal, while, in place of another of its petals, two sepals are developed! Not less remarkable is the figure of a Peach-flower, whose organs exhibit a steady gradation from petals to foliage leaves; and farther on in the volume we meet with an abnormal Rose, entirely devoid of petals, and with sepals which seem to have been trying hard to produce a serrated margin. The stamens of this flower are normally developed, but the pistil (if

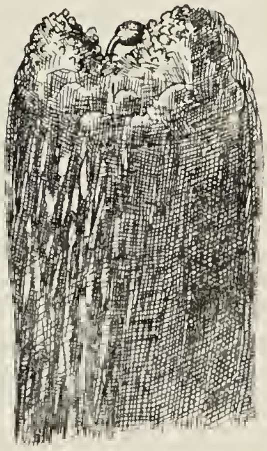


Fig. 313.—Stigma and part of style of a Nerine Lily.

pistil it may be called) is a curiosity, the style being elongated into a green and healthy-looking shoot, bearing some two or three dozen ordinary leaves!

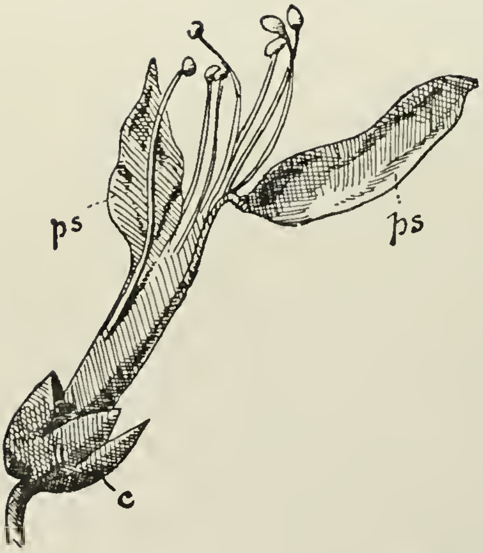


Fig. 314.—Portion of a flower of *Wistaria* with two petaloid stamens (*ps*). (*c*) Calyx (keel wings and standard have been removed).

The "monster" flowers which have come under our own notice are not so singular as those figured in Dr. Taylor's remarkable articles, but they serve no less to illustrate Goethe's law, and as we have in some instances preserved drawings of the flowers, let us say a word or two about them here. The first figure (fig. 314) represents a flower of *Wistaria*, from which the coloured petals have been removed. In this example the abnormally developed organs are the stamens, one of which has a small leaf-shaped purple petal growing out from the centre of the style; while another has developed a similar petaloid organ in place of the anther-lobes. In the second figure (fig. 315) we have a "monstrous" flower of Begonia (*B. Octavia*), whose outer petals—or rather sepals—have been metamorphosed into green leaves, with midrib, veins, etc.

In many species of the genus *Clematis*, the sepals are *petaloid*—that is to say, they are coloured like true petals, while the petals are absent. The former are spoken of collectively as the *perianth*, this being the name applied to the floral envelopes of a flower when calyx and corolla are not easily distinguished. It would be well, perhaps, to keep exclusively to this use of the term, rather than apply it in a loose way to the floral envelopes of any and every flower. In the figure of *Clematis cærulea* (fig. 316), the six petal-like organs (really sepals) constitute the perianth. In the companion figure (fig. 317), which represents the male flower of a Begonia, there are two floral whorls, the inner being true petals, and the outer petaloid sepals.

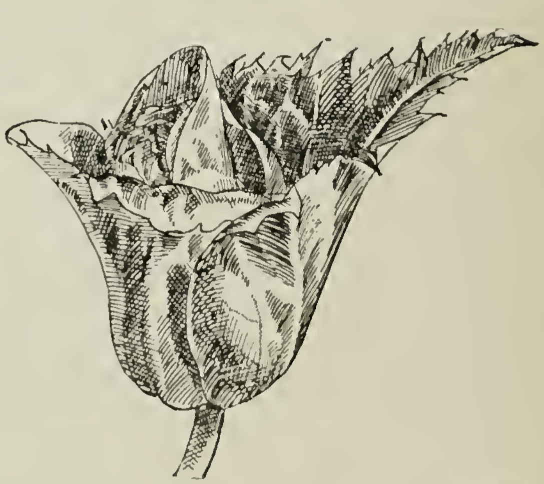


Fig. 315.—Flower of *Begonia Octavia*, with sepals developed as green foliage leaves.

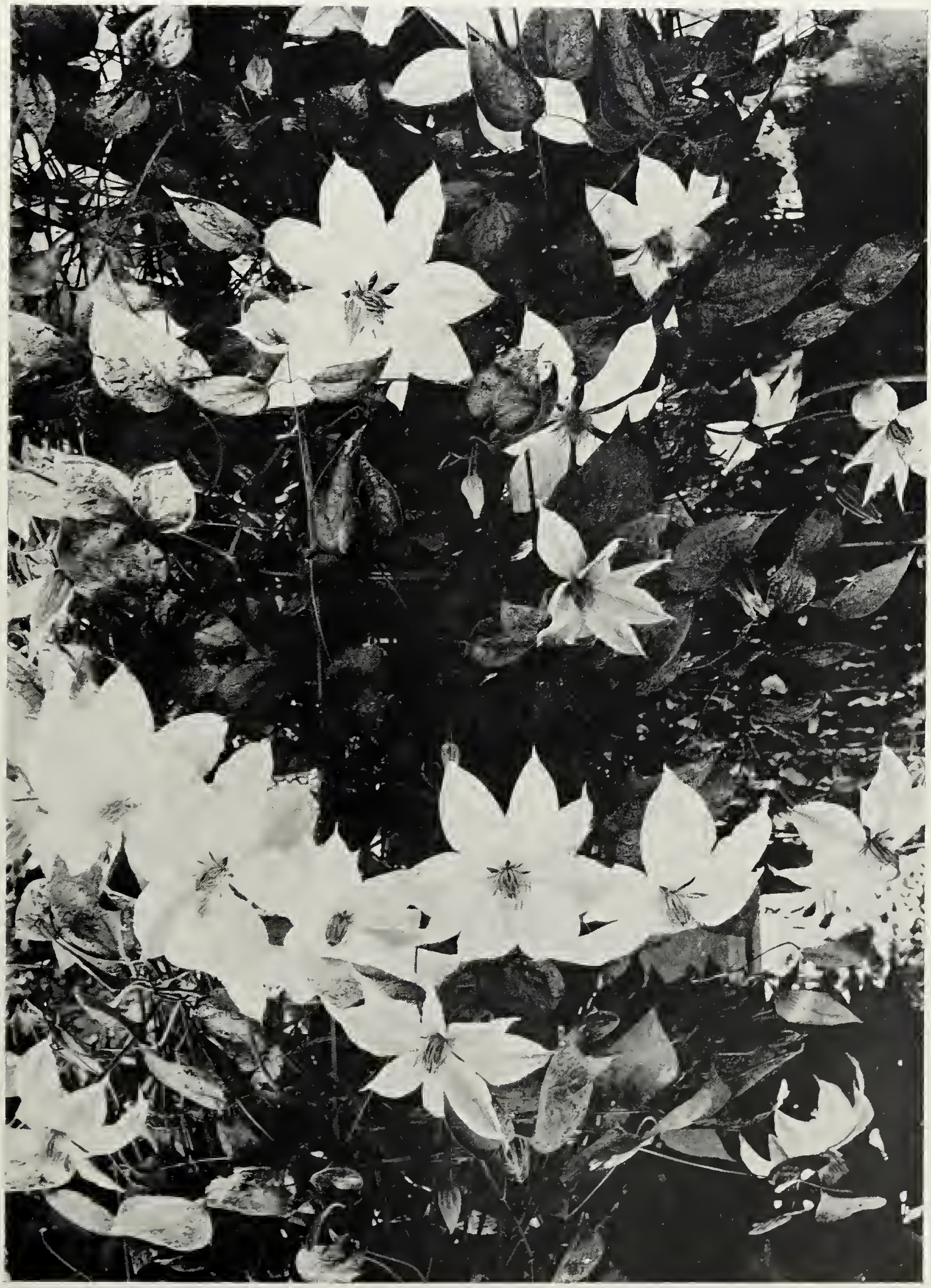


Photo by F. C. Taylor.

Clematis Jackmanni.

A climbing plant of the great Buttercup order, with opposite leaves.

PLATE XVIII.

Probably no flower better illustrates the truth we are considering than the White Water-lily (*Nymphæa alba*), in which the gradual stages of transformation from the green sepals of the calyx to the yellow pollen-producing stamens may be seen to great advantage. We are not speaking now of "monstrous" specimens of the flower (nor were the Begonia and Clematis last alluded to at all abnormal), but of the ordinary White Water-lily; which thus shows, in a permanent fashion, the community which exists between the various members of the flower. For the sepals merge into petals, and the petals into stamens, by such imperceptible gradations that at certain points it is difficult to say to what set of organs particular parts belong. In the drawings (figs. 318-330) made to illustrate the fact, it is easy enough to see that figure *a* with its dark green colouring is a sepal, and that *b*, though of a paler green, is probably a sepal too; but what of the next figure, *c*? This is neither a decided green nor a pure white, but a cross between the two, and it might be called indifferently a sepal or a petal. In the next row (*d* to *g*) we have petals beyond a doubt; but we are again at a loss when we come to figure *h*. Does this figure represent a petal or a stamen? It is broad and white like the former, but the thickening at its apex is of a yellow colour, and has all the appearance of rudimentary anther-lobes. The figure beside it is equally perplexing, and not till we get to *m* do we find a stamen pure and simple, with normally developed style and anther and abundance of pollen. The transition is far more gradual than the drawings might lead one to suppose. In the flower itself a large number of petaloid sepals and stameniferous petals have place between the organs figured; and each differs in some slight degree from its neighbour. Here, then, you have an abiding witness to the facts

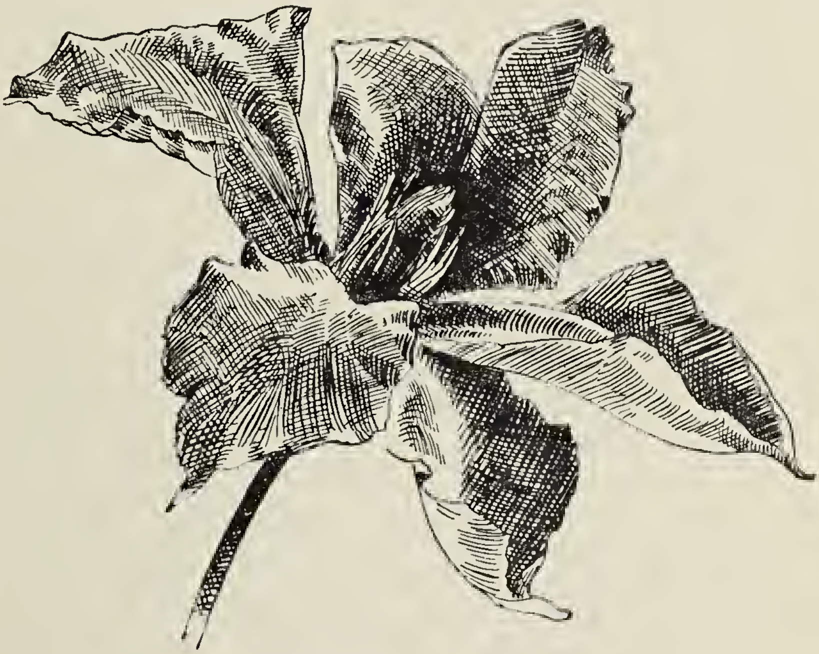


Fig. 316.—Flower of *Clematis cærulea*.

of which we have been treating—a constantly accessible illustration of that homology of structure which seems to exist between the members of every flower. We are now in a position to carry our inquiry a step farther.

A flower being only a modified shoot, it is not surprising that the arrangement of rudimentary floral organs in the bud is analogous to the arrangement of young foliage leaves; and therefore that what has been already said on the subject of prefoliation, or vernation, applies almost equally to the subject of *prefloration*, or *æstivation*. Such, indeed, is the fact. The word "æstivation" is derived from the Latin *æstas*, summer, this being the season when most flowers begin to open, just as "vernation" is derived from the Latin *ver*, the season specially associated with the expanding of leaf-buds. Moreover, the terms which are employed in describing the various modifications in the one, answer almost equally for the other; though flower-buds exhibit certain arrangements which are peculiar, and for which special terms have had to be invented.

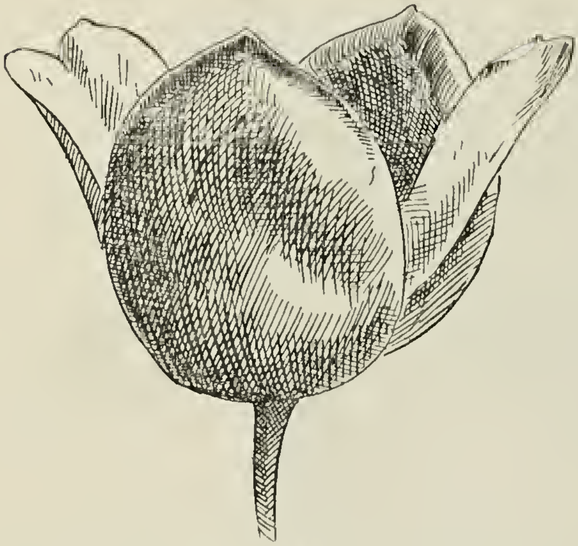
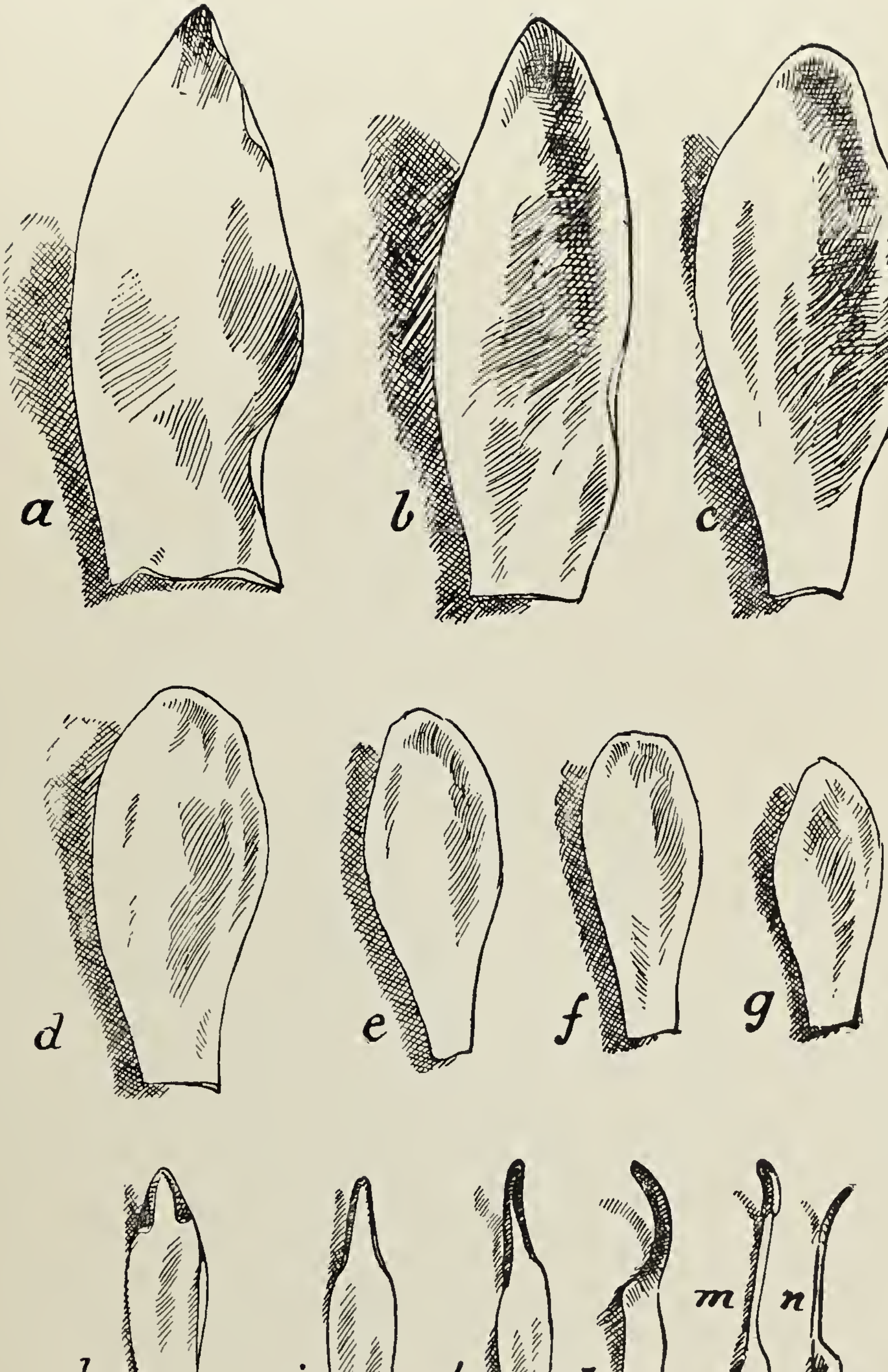


Fig. 317.—Male flower of Begonia, consisting of two floral whorls—the inner, petals; the outer, petaloid sepals.

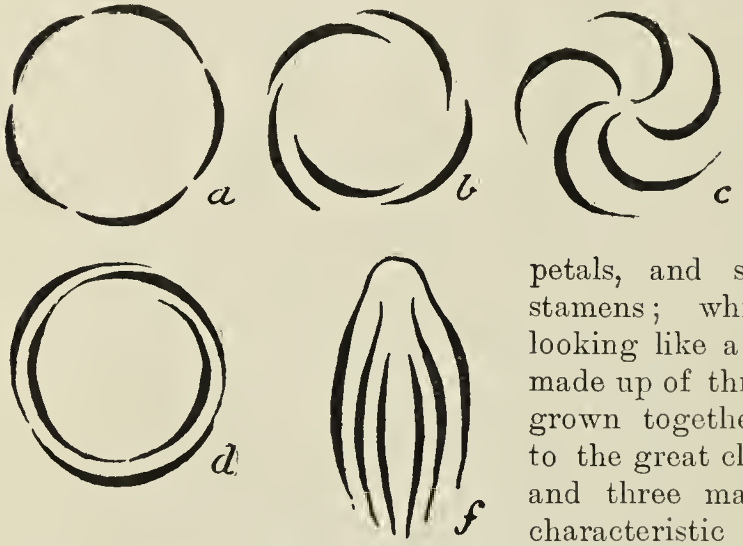
It is sufficient here to observe that all the various modifications may be arranged under two heads, the *circular* and the *imbricated* or *spiral*; the former comprehending those varieties in which the component parts of the whorl (the sepals of the calyx, petals of the corolla, and so forth) are arranged in a circle and nearly on the same level; and the latter including those forms in which the said parts overlap one another, and have a more or less spiral arrangement, the consequence of their being placed at slightly different levels. For interesting varieties of circular æstivation the calyx of the flower-buds of the Lime (*Lilia*) and Hollyhock (*Althæa rosea*) and the folded corolla of the Potato (*Solanum tuberosum*) may be profitably examined; while the Camellia, Rose, Bindweed (*Convolvulus*), Snapdragon (*Antirrhinum*), and St. John's Wort (*Hypericum*) offer examples of the chief varieties of spiral æstivation (figs. 331-335).

We approach more interesting ground when we begin to speak of the *expanded* flower. The question of form and arrangement again meets us



Figs. 318–330.—Sepals, petals, and stamens of White Water-lily.

on the threshold, but the study of the structural variations of flowers by no means confines one to the acquisition of name-lists or of tedious and meagre definitions. The question is one of scientific importance, involving as a preliminary step the arrangement of multitudes of appearances under primary points of view, and their classification according to rule and exception; by which means alone a discovery of the actual laws of Nature is rendered possible. Now, manifold as are the structural arrangements of flowers, the variations really concern only a few simple subjects, and when these are grasped the investigation of the causes which produce the differences in the whole floral world is by no mean a hopeless undertaking (Schleiden).



Figs. 331-335.—Æstivation of flowers. (*a*) Valvate. (*b*) Imbricate. (*c*) Contorted or twisted. (*d*) Quincuncial. (*f*) Vexillary.

The *subjects of variation* are, in fact, four; and the first to be mentioned is *number*. A Lily, for example, has three sepals, three petals, and six (*i.e.*, twice three) stamens; while its pistil, though looking like a single organ, is really made up of three carpels which have grown together. The Lily belongs to the great class of Monocotyledons, and three may be said to be the characteristic number of that class. In the floral whorls of Dicotyledons, on the other hand, threes are a rarity; nor can any number be said to be characteristic, though fours and fives are very common. A Fuchsia has four coloured sepals, four petals, twice four (*i.e.*, eight) stamens, and four carpels. A flower of Cherry, on the other hand, has its two outer whorls, the calyx and corolla, in fives, and its stamens form a multiple of five—namely, twenty. The ovary does not follow the rule—it is solitary; nor is this case by any means an exceptional one, the parts of the pistil in the majority of Dicotyledons being fewer than in the other whorls.

It might easily be shown that whorls of flowers correspond to cycles of leaves, but it would be exceeding our present limits to push our inquiries farther in this direction.

The second of the four subjects of variation is *cohesion*. This term is applied by botanists to the union of *like* parts in a flower, as of sepal with sepal, petal with petal, stamen with stamen, and so forth. Both

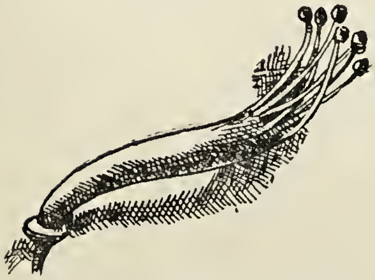


Fig. 336.—Monadelphous stamens of Laburnum.

the calyx and corolla of a Primrose are good examples of cohesion. Here the five sepals unite in a tube and form what is called a *gamosepalous* calyx; the five petals are also fused together, and so the corolla is described as *gamopetalous.* A free-sepalled calyx is said to be *polysepalous*; a free-petalled corolla, *polypetalous.* In the Laburnum (*L. vulgare,* fig. 336) the filaments of the stamens cohere so as to form a tube—they are *monadelphous.* In the Dandelion (*Taraxacum officinale*) it is the anthers which unite, and the stamens are said to be *syngenesious* (fig. 337). Lobelia shows both conditions. Stamens which are united into two, three, or more groups are termed *di-*, *tri-*, and *polyadelphous* respectively.

Then as to carpels. These may be united in two ways. "If we take a pea-pod, we shall find that it closely resembles a narrow, long-pointed leaf folded down the middle, with the edges in contact. Such is really Nature's method of making a carpel, of course greatly modifying the leaf for its new purpose (figs. 338, 339). The peas, *i.e.*, the ovules, are always produced down the united margins in two rows, *i.e.*, one row on each margin. Now suppose we take two or more pea-pods. Place them with their margins in contact, and then compress them so that the *sides* will meet, and imagine them to have thus *grown* in contact. They would then be in a state of cohesion, and a cross section through the ovaries would reveal as many chambers as there are carpels. That is one way. This is well seen in the pistil of the Bluebell (*Scilla nutans*) [and the Purple Spring Crocus (*Crocus vernus*, fig. 340)]. Another may be illustrated as follows: Take two or more pods, but this time crack them open down the margins where the peas are (but not down the opposite side); half the peas will now be found on one margin and half on the other. Now place the open pods in a circle, edge to edge, and imagine the edges only to become coherent. There will thus be

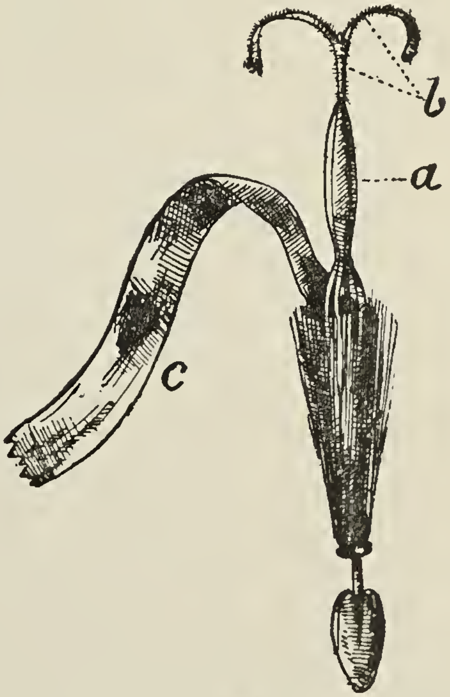


Fig. 337.—Floret of Dandelion. (*a*) Cohering anthers. (*b*) Extremity of style. (*c*) Ligulate corolla.

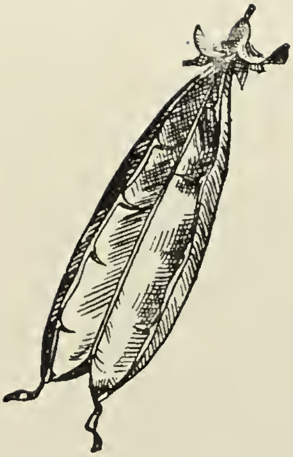


Fig. 338. — Carpel of Common Pea (*Pisum sativum*).

Fig. 339. —Leaf of same.

one large chamber, with as many double rows of ovules as there are carpels. The Violet (*Viola*) and Mignonette (*Reseda lutea*, fig. 341) will illustrate this condition" (Henslow).

Pistils which are made up of two or more carpels are described as *compound*, to distinguish them from *simple* pistils, which contain only one carpel. Yet it must not be supposed that the carpels of all compound pistils cohere. In the Buttercup, for example, they are free and distinct (fig. 342), whence they are called *apocarpous*. In Begonia, on the other hand (fig. 343), they are united, or *syncarpous*.

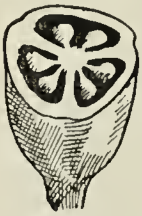


Fig. 340.—Transverse section of ovary of Purple Spring Crocus, showing the three separate chambers.

We come now to the third subject of variation—namely, *adhesion*, or the union of *unlike* parts of a flower. A calyx uniting with a corolla, a corolla with stamens, and stamens with pistil, would all be instances of adhesion; though the first-named manner of union is not common. Very seldom do sepals unite with petals—or, indeed, with members of any other floral whorl. The adhesion of petals and stamens is, however, common enough, and may be looked for as a thing of course *whenever the petals of a flower cohere.** A well-known example is the Foxglove (*Digitalis*). On opening one of the flowers the four stamens may be seen adhering to the inner side of the bell-shaped gamopetalous corolla. The anther-lobes and a part of each of the filaments are free, but the lower portions are united to the corolla, upon which they appear as prominent ridges. Adhesion between stamen (or stamens) and pistil is comparatively rare, but when this consolidation of male with female organs takes

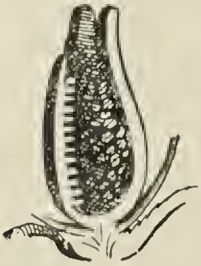


Fig. 341.—Longitudinal section of ovary of Wild Mignonette, showing the single chamber.

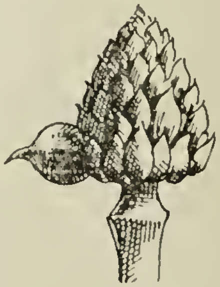


Fig. 342.—Carpels of a Buttercup. One only mature.

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* Flowers of the Heath family (*Ericaceæ* are among the few exceptions.

place they are called *gynandrous*, from the Greek *gunē*, a female, and *andros*, male.

The fourth and last subject of variation is *form*. The old idea that the beautiful and oftentimes singular shapes of flowers were designed by the Creator chiefly—if not exclusively—for the pleasure of man, has been long discarded by thoughtful minds; and in the present day one hardly needs to be told that the manifold varieties of floral form are, in the vast majority of cases, so many adaptations for the admission or exclusion of insect visitors, and for facilitating the dispersion of the pollen. In the zest of what is still, in effect, but a new discovery, many facts relating to this subject have doubtless been distorted, and theories built upon them which will have to be modified or withdrawn; yet the great central fact remains, and it is one of wide-reaching importance. In succeeding chapters some account will be given of the peculiar contrivances by means of which insects are lured to certain flowers and are made the unconscious instruments of pollination; but at present it is better to direct our attention to typical rather than to special forms.

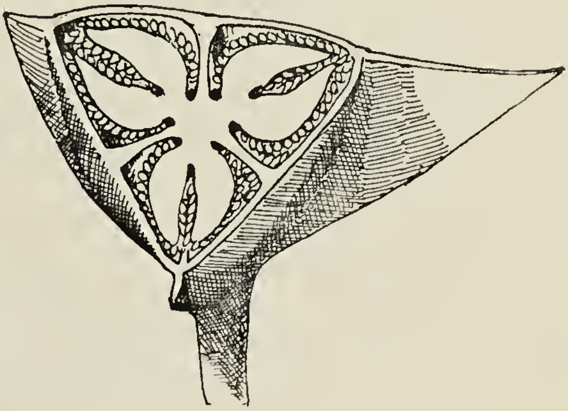

Fig. 343.—Section of the syncarpous ovary of a Begonia, showing axial placentation.

It should be further remarked that the subject of Form has particular, though by no means exclusive, reference to the calyx and corolla. Many uses have been enumerated for these floral envelopes. In the earlier stages of the flower they serve as a protection to the delicate cells of the immature stamens and pistil; and at a later period they perform the same kindly offices for the pollen, which might otherwise be blown away prematurely by the wind, or be stolen by unbidden insect guests, or rendered abortive in consequence of injuries from rain and dew. In many plants, again, they assist in bringing about *autogamy*—that is, the fecundation of the flower by its own pollen; while in others, their powerful odours and vivid colours, by attracting pollen-dusted insects, are instrumental in effecting a precisely opposite result—namely, *allogamy* or fecundation by pollen from another flower. Lastly, the floral envelopes may act as a protection to the nectar, which, though oftenest secreted at the base of those organs, is not infrequently found in hollows and warty projections of the stamens and pistil.

Beginning with the outermost floral whorl or calyx, let us try to realise, by means of a few examples drawn from familiar flowers, some of the facts to which we have been referring. We can conceive of no easier or more interesting way of acquiring a knowledge of the morphology of floral organs than by considering them in relation to the functions which they fulfil.

In some flowers—as the Carrot (*Daucus Carota*, fig. 344)—the calyx is a very inconsiderable set of organs; while in others, as the Alpine Liane (*Atragene alpina*), *Delphinium consolida*, and the curious *Molucella*, it forms the most attractive part of the flower. This is notably the case with the shallowly bell-shaped calyxes of the last-named flower (fig. 345), to which is due the very singular appearance of the densely packed axillary flowers, which are arranged in whorls on the stems. *Delphinium consolida* has its posterior sepal prolonged as a *spur*, into which the solitary petal (or, rather, gamopetalous corolla), which is also spurred, fits as neatly as a lady's finger in a glove. Now in this flower (as well as in most species of Larkspur) the petaloid spur is the nectary, so that the ensheathing sepal of the calyx is simply a beautiful arrangement for the protection of the nectar. The Garden Nasturtium (*Tropæolum majus*) is also furnished with a spurred calyx, but the corolla has no such appendage; nor is one required, for, in this instance, the sepaline spur is itself the nectary (fig. 347).

In the Monkshood (*Aconitum*) we have the example of a helmet-shaped or *galeate* calyx (fig. 348). The two posterior sepals unite to form the helmet; and the structure, which reminds one of the head-armour of some Homeric hero, affords excellent protection to the anthers and nectaries. The two lateral sepals are serviceable in another way, as they form a platform for humble-bees, which play an important part in the pollination of the flower (fig. 349).

The urn-shaped or *urceolate* floral receptacle of the Rose (*Rosa*)—that green shiny swelling which afterwards changes to a red colour and forms the outer covering of the berry—is often spoken of as the calyx; but it is more correct to restrict this term to the five segments which spring from the somewhat contracted margin of the urn, and which, in such cases, are simply free sepals (fig. 350). As these sepals remain after the

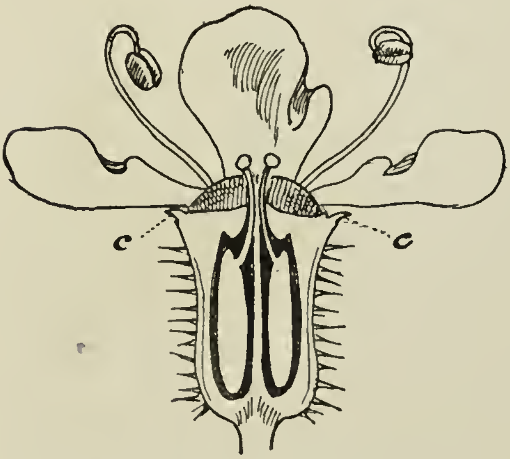

Fig. 344.—Section through epigynous flower of Carrot. (c) Calyx.

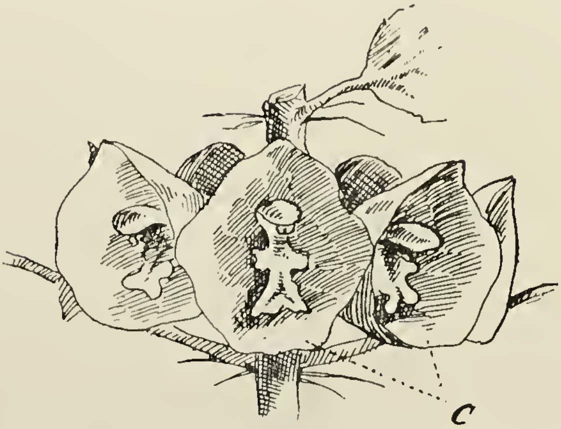

Fig. 345.—Whorl of flowers of *Molucella lævis*, with singular bell-shaped calyxes (*c*).

fruit has ripened, the calyx is said to be *persistent*—a feature which the Rose possesses in common with the Henbane (*Hyoscyamus niger*, fig. 351), Mallow (*Malva*), Pear (*Pyrus communis*), Apple (*Pyrus Malus*), Gooseberry (*Ribes Grossularia*), Strawberry (*Fragaria vesca*), and Melon (*Cucurbita*). In other flowers, however—the Buttercup (*Ranunculus*) will serve as an example—the calyx is *deciduous*—that is to say, it falls off before the fruit ripens; while in a few cases, as the Poppy (*Papaver*), *Eschscholtzia* (fig. 352), and those interesting Malayan shrubs, the Pternandras (fig. 353), where its chief purpose appears to be to protect the young and insecurely fastened petals of the bud, it drops off as soon as the flower opens. Such a calyx is said to be *caducous*. Some persistent calyxes are *accrescent*—that is, they continue to grow after the flowering time, like the Winter Cherry (*Physalis Alkekengi*), a solanaceous plant often cultivated in gardens. The highly coloured inflated calyx of this plant is, indeed, its sole attraction, for the cohering sepals so enclose the other organs of the flower as to hide them completely from view (fig. 354).

We mentioned the Strawberry just now, and in fig. 355 you will notice that the calyx consists (apparently) of a *double* whorl of sepals—in other words, of two calyxes*—and some botanists distinguish them by calling the outer whorl the *epi-calyx*. Whatever may be the general purpose of an epi-calyx, it certainly renders good service in the case of the Strawberry by protecting the young "fruit" from the depredations of insects—not of winged insects, of course, but of those which approach the coveted object by way of the stalk.

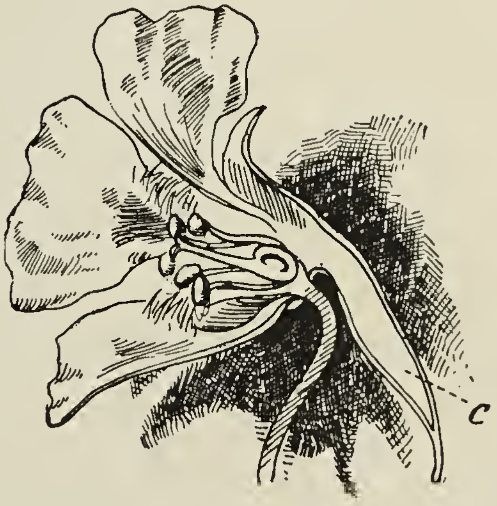

Fig. 346.—Section through flower of *Tropæolum majus*, showing spurred calyx (*c*).

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* Another opinion is that there is only one whorl of sepals, the outer structures being regarded merely as stipular growths thereupon.

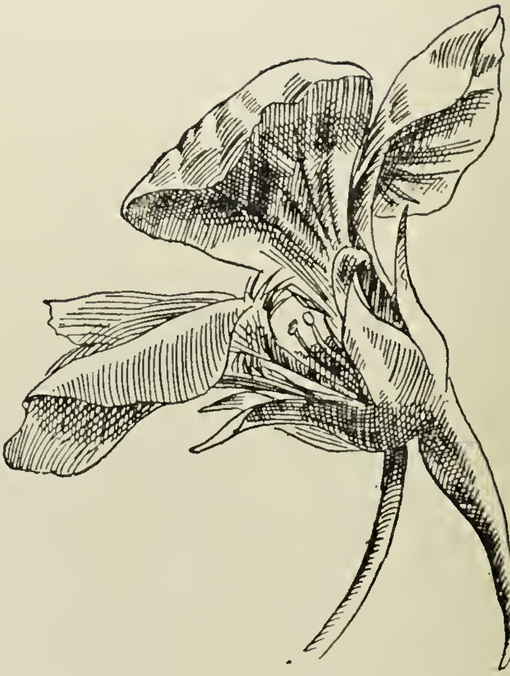

Fig. 347.—Flower of *Tropæolum majus* with spurred calyx.

Against winged insects a more or less inflated calyx is often a first-rate protection; for besides putting them to the labour of gnawing through the calyx before the proboscis can be inserted, it serves to hold them at a distance even when that difficulty has been surmounted. Take, for instance, the sack-shaped (*saccate*) base of the calyx of Honesty (*Lunaria*, fig. 356), and conceive how difficult it would be for one of the smaller tissue-gnawing insects to get at the interior of the flower. To bite a hole large enough for the insertion of its proboscis would not be sufficient; the hole would have to be widened till it was large enough to admit the insect itself, otherwise the little plunderer would be too far off to reach the nectar. In flowers where the inflation of the calyx is greater, the difficulties of gaining access to the interior are, of course, proportionately increased. We must not stop to particularise, though the *globose* calyx of the Winter Cherry, to which we referred a moment or two ago, would afford a ready illustration. The whole subject will be before us again in the next chapter, when we shall deal with the contrivances in flowers for the exclusion of unbidden guests, one of the most fascinating themes that the botanical writer has to handle.

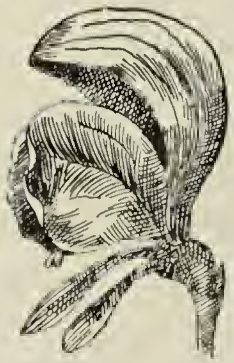

Fig. 348.—Flower of Monkshood, showing helmet-shaped upper sepal.

The other forms of calyx which remain to be spoken of may be treated in connection with the forms of the corolla, to which we now invite attention.

Let us commence with a perfectly symmetrical or *regular* flower—that is to say, one the halves of which, produced by all possible sections, are similar; such, for example, as the Wallflower (*Cheiranthus Cheiri*). Here we have a calyx of four sepals, two overlapping the edges of the other two so as to form a sort of false tube (a true *tubular* calyx may be seen in the Primrose—*Primula vulgaris*), and these serve as a support to the four *clawed* petals, which, it will be noted, are arranged in the form of a Maltese cross, Hence, the corolla is described as *cruciform.* It would be going too far from our subject to show how the several correlated points of structure in this flower are connected with its fertilisation by insect agency; but we may just notice how admirably the cruciate corolla is adapted as a landing-stage for nectar-seeking visitors.

In contrast to the Wallflower, take a Pansy (*Viola*, fig. 357). A Pansy is a good example of an *irregular* flower. By cutting through the centre perpendicularly we get two similar halves, but in no other way can the flower be divided symmetrically. Flowers exhibiting this kind of bilateral symmetry are known as *monosymmetrical* or *zygomorphic* (Greek *zeugnumi*, I join, and *morphe*, a shape). Flowers the petals of which are placed like the spokes of a wheel, and which may therefore be divided vertically into similar halves through two or more planes, are termed *actinomorphic* (Greek *aktin*, a spurious form of *aktis*, a ray, and *morphe*). All regular flowers are actinomorphic : most irregular flowers are zygomorphic. Some flowers cannot be symmetrically divided in any plane—they are asymmetric.

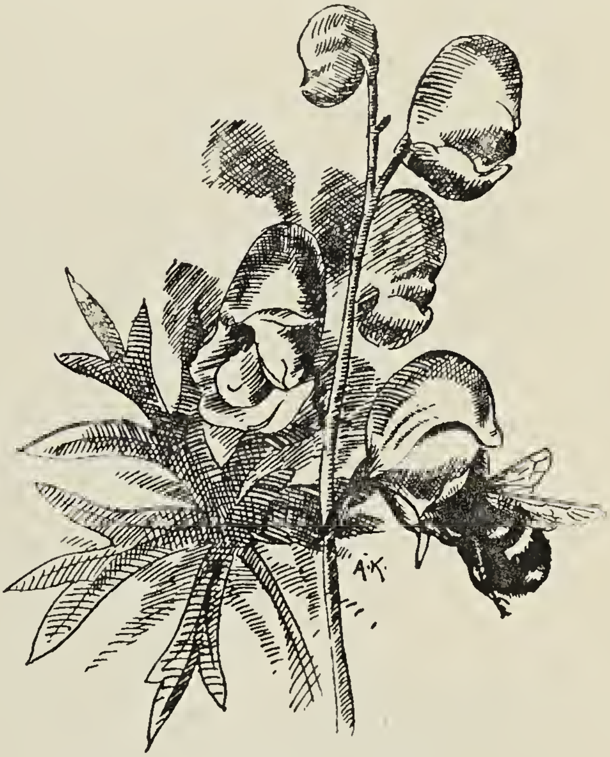

Fig. 349.—Humble-bee entering flowers of ***Aconitum napellus.***

There is a curious fact about the Pansy. What appears to be the lowermost petal is really the upper, for the flower has been reversed. It has been thought that the purpose of the twist is to strengthen the flower and thus to enable it to sustain the weight of insects. When a honey-bee visits a Pansy, it almost always turns round on alighting, and sucks with its head downwards, and the flower is bent down by the insect's weight—a circumstance which indirectly bears out this idea. Notice the streaks of colour on the petals, all leading towards the centre of the flower. They are *honey-guides* for the insect visitors—*pathfinders*, as some have named them. There will be more to say about these pathfinders on a future occasion, but allusion is made to them here by way of emphasising the contrast which the petals of this flower present to those of another

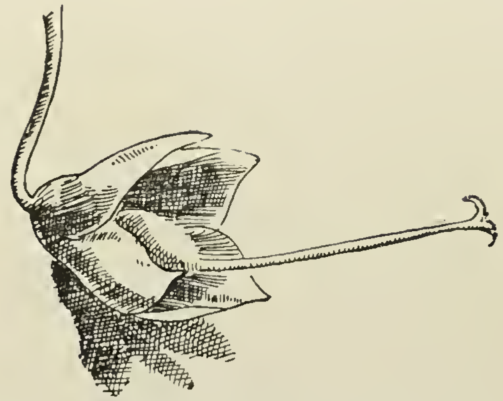

Fig. 350.—Persistent polysepalous and inferior calyx of Foxglove (*Digitalis*).

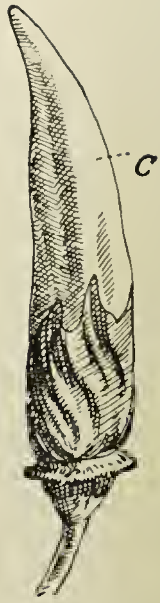

Fig. 352.—Caducous calyx of *Eschscholtzia*. (*c*) Calyx.

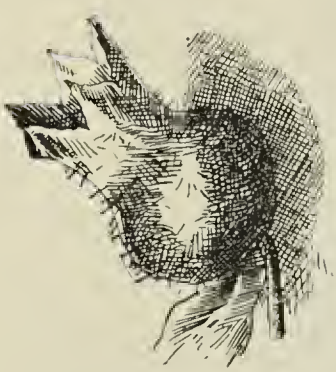

Fig. 351.—Urceolate persistent calyx of Henbane.

common flower, the White Campion (*Lychnis vespertina*, fig. 358). The pure white corolla of this species of Campion has no guiding marks; in this case they would be of no service, for the flower expands in the evening, and insects are attracted to it by its whiteness. There are five petals, attached by claws to the base of a tubular calyx, and these are the characteristic features of a *caryophyllaceous* * corolla. The Maiden Pink (*Dianthus deltoides*), Carnation (*D. Caryophyllus*), and Catchfly (*Silene*) exhibit the same features. The *rosaceous* corolla consists of five petals, too, but they are without claws: the Buttercup (*Ranunculus*, fig. 359) is a good example.

Notice how the corolla of the White Campion is constricted near its upper end by the toothed or *dentate* calyx. This is another contrivance for shutting out unwelcome visitors. Only a thin proboscis, at least three-fifths of an inch long (such, for instance, as that of the small Elephant Hawk-moth [*Chærocampa parcellus*], which often visits and cross-pollinates the flower), could reach to the fleshy part of the ovary where the honey

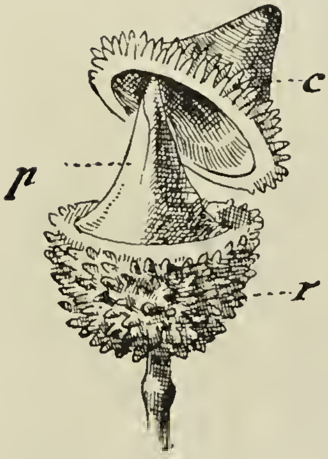

Fig. 353.—Flower-bud of *Pternandra cordata*. (*p*) Petals. (*c*) Caducous calyx. (*r*) Receptacle.

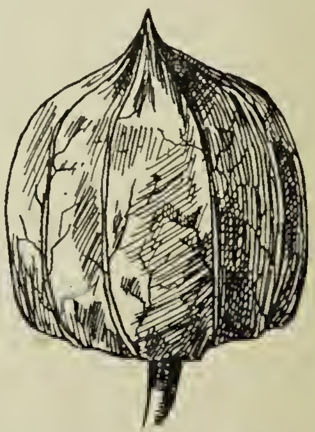

Fig. 354.—Accrescent calyx of Winter Cherry.

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* Greek *karuophullon*, properly "nut-leaf," an Indian plant, the Clove-tree.

is stored. In fact, both the calyx-tube and the elongated claws of the petals assist in preserving the nectar for those insects whose visits are really serviceable to the plant. In flowers with salver-shaped (*hypocrateriform*) corollas, like the Primula and Common Lilac (*Syringa vulgaris*), the tubes formed by the cohering petals answer much the same purpose as the clawed bases of caryophyllaceous corollas, and also protect the pollen from drops of rain and dew—the latter an important consideration in the case of plants which dwell amid mountain-mists, like the delicate species of *Primulaceæ* belonging to the genus *Androsace*, and many species of Phlox (fig. 361). "If flowers of *Aretia glacialis*, a plant growing on the moraines of glaciers, are examined after a shower," says Kerner, "it is found that every one has a drop resting upon it which slightly compresses the air in the narrow tube of the corolla, but cannot reach the pollen upon the anthers lower down the tube. A subsequent shake or puff of wind causes the drops to roll off the limb of the corolla, or else they are got rid of by evaporation; in either case, the flower becomes once more accessible to insects." Salver-shaped corollas must be distinguished from *rotate* or wheel-shaped corollas, such as we get, for instance, in the purple-flowered Woody Nightshade (*Solanum Dulcamara*, fig. 362). In the former the tubes are long and narrow, in the latter they are short; but in both the limb is placed at right angles to the tube.

We come now to the *tubular* corolla. From what has been said about the uses of caryophyllaceous and salver-shaped corollas, the purpose of this third form may be readily divined. It, also, has reference to insect-pollination. The Common Honeysuckle (*Lonicera Peryclymenum*, fig. 363) may serve as an example. The sweet-scented flowers are adapted for fertilisation *exclusively* by long-tongued

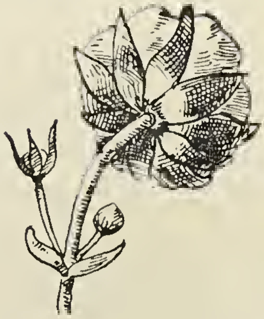


Fig. 355.—Wild Strawberry (*Fragaria vesca*), showing calyx and epicalyx.

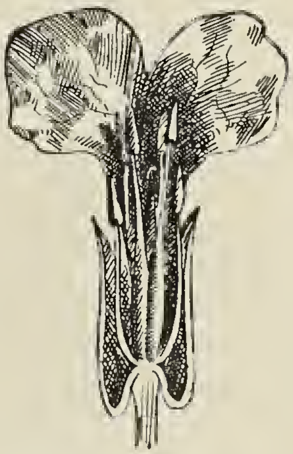


Fig. 356.—Section of flower of *Lunaria*, showing saccate calyx.

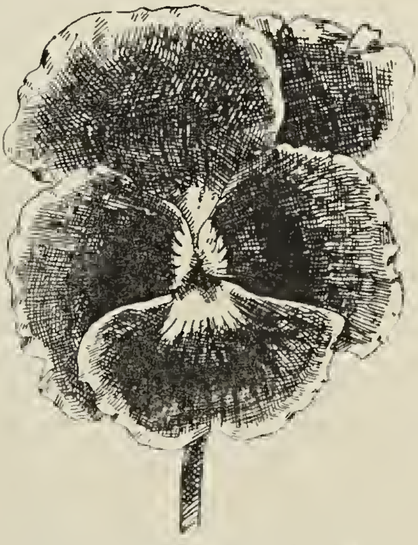


Fig. 357.—Irregular flowers of Pansy.

crepuscular and nocturnal moths; and why? Because the wax-like tubes are long and narrow—too long for short-tongued insects to reach the honey while standing at the mouth of the flower, and too narrow to enable them to descend bodily to the nectary. As a matter of fact, the flowers bloom at the very season when hawk-moths are most abundant—that is, during May and June—and they exhale their perfume most strongly in the evening, when these moths are on the wing.

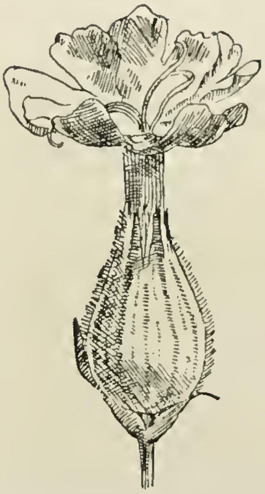


Fig. 358.—Female flower of White Campion.

Another form of gamopetalous corolla which must not be passed over is that which, from its resemblance to a funnel, has received the name *infundibuliform.* The name is less elegant than the flower to which it is applied. Fancy describing the delicate white chalices of our beautiful Hedge Convolvulus (*C. Sepium*, fig. 364) as infundibuliform corollas! Yet that is what the necessities of botanical nomenclature impose upon us. Funnel-shaped flowers have not such a reputation for exclusiveness as have those of tubular and salver shape; and it has been observed of the Hedge Convolvulus that all sorts of thrips and little flies frequent the flowers by day, sheltering and feeding there, though they confer no benefit in return. Only on bright, moonlight nights, when the sphinx-moths are about, does the plant reap any advantage from its visitors. A friend of the naturalist Delpino, standing by a hedge overgrown with this Bindweed, was able to capture numbers of one species of sphinx-moth (*S. convolvuli*) simply by closing with finger and thumb the orifices of the flowers as the moths inserted their heads.

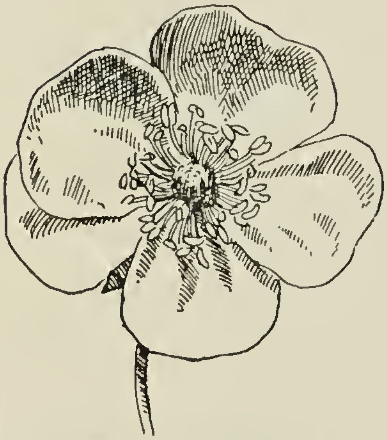


Fig. 359.—Rosaceous corolla of Buttercup.

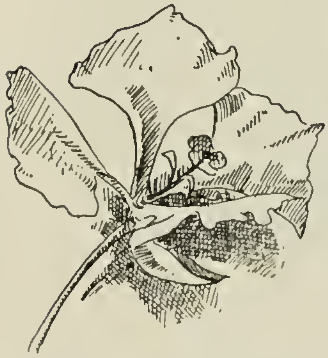


Fig. 360.—Corolla of *Clarkia*, showing clawed petals.

A form of corolla closely related to the infundibuliform is the *campanulate*, or bell-shaped. We have an example of a *regular* campanulate flower in the well-known Canterbury Bell (*Campanula Medium*, fig. 365), and of an *irregular* or *oblique* campanulate flower in the equally well-known Foxglove (*Digitalis*, fig.

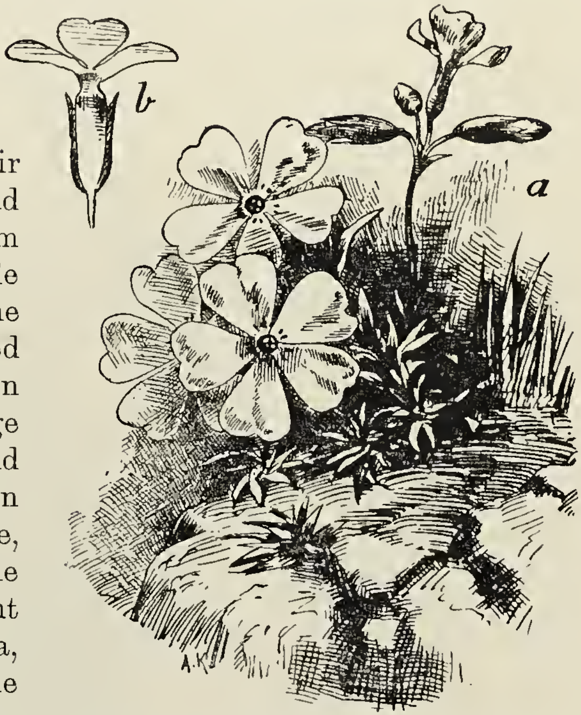


Fig. 361.—Snowy Phlox (*Phlox subulata nivalis*) with salver-shaped corollas. (*b*) Flower in section.

366). The wide bell-shaped corollas of Campanula are specially adapted for humble-bees; but the flowers number other kinds of bees among their visitors, and numberless beetles and small flies use them as shelters from the rain or make the comfortable bells their night quarters. The Foxglove is also specially adapted for humble-bees, for, says Hermann Müller, "no other insects are large enough to touch the stigma and anthers with their backs when creeping into the tube." They are, in fact, the only fertilisers of the Foxglove. Possibly the enlargement of the under side of the corolla, which gives the irregularity to the flower, is intended as a landing-stage for the insect (it is certainly so used), and may also be an arrangement to relieve the strain upon that part of the bell where the weight of the humble-bee would most press.

We find ourselves among flowers of more intricate construction when we come to speak of *labiate* or lipped corollas. The White Dead-nettle (*Lamium album*), one of the commonest of our weeds, is the flower chosen for illustration (figs. 367, 368). The corolla is decidedly irregular, and on a cursory examination it is not easy to distinguish from one another the five cohering petals which compose it; though by bearing in mind the simple rule that *petals should alternate with sepals*, the difficulty will vanish. Guided by this rule it will be found that the lower lip or cleft piece in front (*a*) is one petal, that the pointed and inconspicuous appendages (*b b*) on either side the corolla-tube are the rudiments of two more, and that the remaining pair form the overshadowing hood or upper

Fig. 362.—Flowering branch of Woody Nightshade.

lip of the flower. "We can estimate by direct observation," says Hermann Müller, "how perfect the adaptation of this flower is to bees' [humble- or other large bees'] visits. The bee alights on the under lip, and in doing so thrusts its head between the broad lateral lobes of the mouth, clings with its fore-feet to the base of the under lip, and with its mid- and hind-feet to the two lobes of the under lip; then if its proboscis is not less than ten millimetres [about two-fifths of an inch] long, it can at once reach the base of the flower. While sucking, the thorax, and in the case of small workers the base of the abdomen also, fills up the space between the upper and lower lips, and the vaulted upper lip fits the bee's back, which is pressed against the stigma and the open face of the anther."

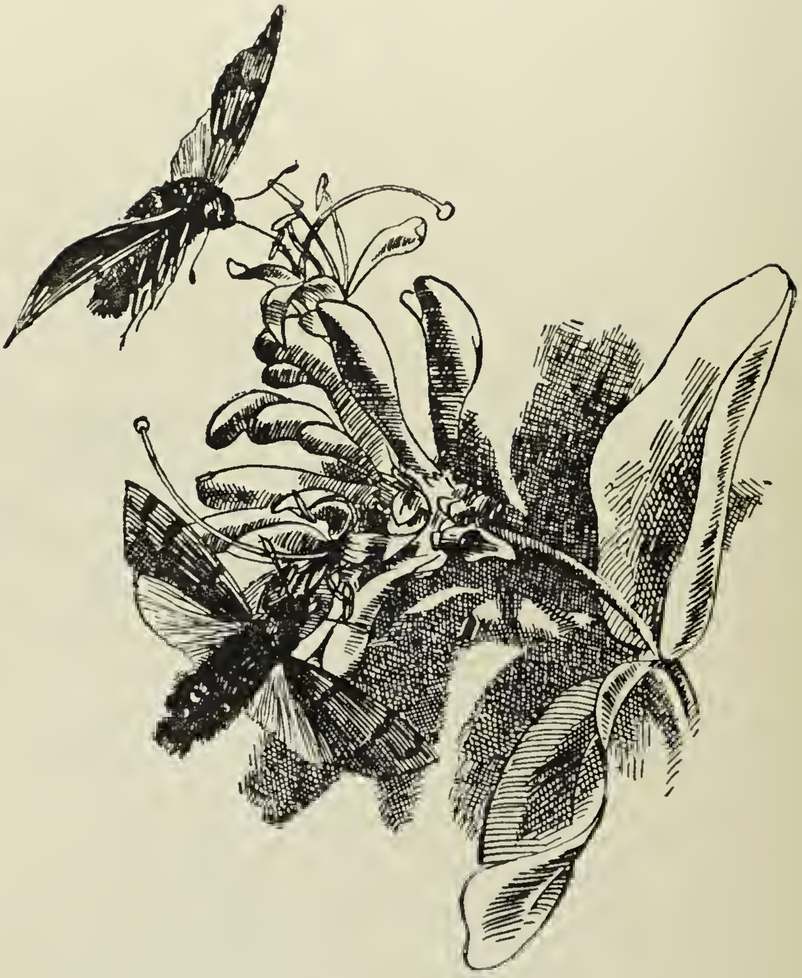


Fig. 363.—Common Honeysuckle visited by Humming-bird Hawk-moths (*Macroglossa stellaterum*).

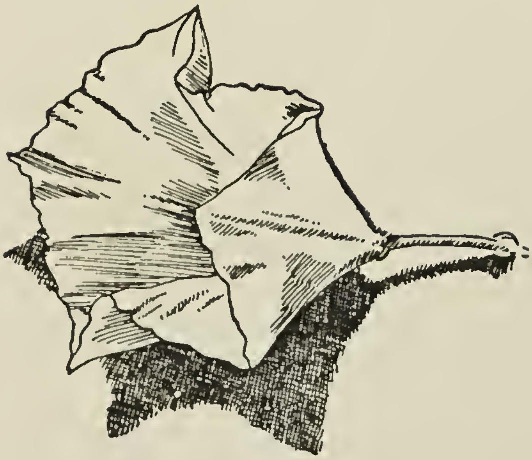


Fig. 364.—Funnel-shaped (infundibuliform) corolla of Great Hedge Convolvulus.

Personate or mask-like corollas, of which the Toadflax (*Linaria*) and Snapdragon (*Antirrhinum*) offer convenient examples, are even more elaborate in their construction than the labiate form. They resemble the latter in possessing a double lip, the essential point of difference being that their lower lips approximate to the upper, so as to close the orifice of the tube or throat. In the Toadflax (fig. 369) this arrangement shuts out flies and beetles, which lack the requisite strength to force an entrance, while the length of the nectar-storing spur excludes short-lipped bees, which are not so incapable of breaking in. Thus the flowers become exclusively adapted for the long-tongued species, by which, indeed, they are diligently visited. The Toadflax, it may be noted in passing, is one of those flowers which, though normally irregular, will sometimes become regular by producing in all their petals or sepals the very feature which is the cause of their irregularity. In the flower in question, the peculiarity is that each of the five petals, by virtue of this excess of irregularity, produces a spur, while the upper part of the flower loses its personate character and becomes regular (figs. 369, 370). The wonder excited in the mind of the great Linnæus by this phenomenon led him to apply to it the name *peloria*, from the Greek word *pelōron*, a monster. Of course, in a normally and regularly spurred corolla, like the Columbine (*Aquilegia vulgaris*, figs. 371, 372), the term "peloria" would not be applicable.

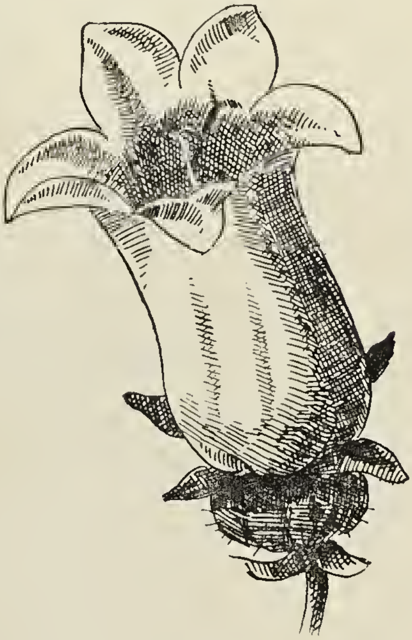


Fig. 365.—Campanulate corolla of Canterbury Bell.

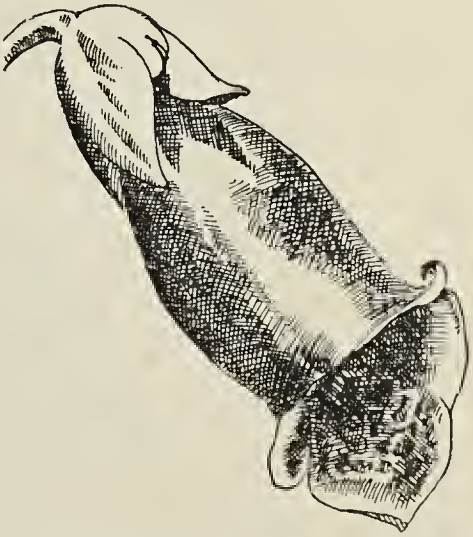


Fig. 366.—Obliquely campanulate corolla of Foxglove.

The arrangement in the personate corolla of the Snapdragon (fig. 373) is similar to that of Toadflax, though not identical. Here, as there is no spur to keep off smaller bee-intruders, the entrance is more firmly closed. and it is only when the flower is old and beginning to wither that it opens its door to such visitors. The flower is, indeed (to quote an expression of Lord Avebury), "a strong box of which the humble-bee only has the key." This guarding of the entrance is a necessary precaution, for if flies and small bees were admitted from the first they would simply pilfer all the honey, and the flower would be less diligently visited by its chief fertilisers, the humble-bees. Ants and small flies, however, will often squeeze their way in, their great difficulty being rather how to get out than how to gain an entrance—a circumstance referred to by Mr. Knapp in his charming *Journal of a Naturalist.* "It has not perhaps been generally observed," he writes, "that the flowers of this plant—'bulldogs,' as the boys call them—are perfect insect traps; multitudes of small creatures seek an entrance into the corolla through the closed lips, which upon a slight pressure yield a passage, attracted by the sweet liquor that is found at the base of the germen [ovary]; but when so admitted, there is no return; the lips are closed, and all advance to them is impeded by a dense thicket of woolly matter, which invests the mouth of the lower jaw.

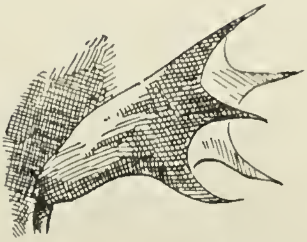


Fig. 367.—Bilabiate five-toothed calyx of White Dead-nettle.

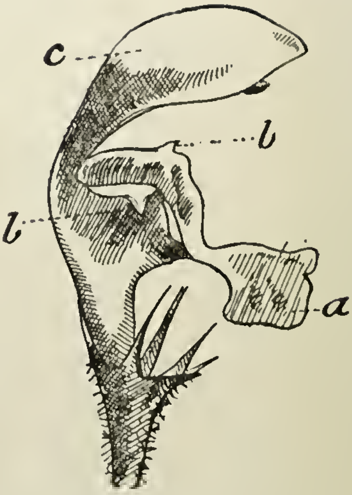


Fig. 368.—Flower of White Dead-nettle.

Smooth lies the road to Pluto's
gloomy shade;
But 'tis a long unconquerable pain
To climb to these ethereal realms
again.

But the Snapdragon is more merciful than most of our insect traps. The creature receives no injury when in confinement; but, having consumed the nectareous liquor, and finding no egress, breaks from its dungeon by gnawing a hole at the base of the tube, and returns to liberty and light."

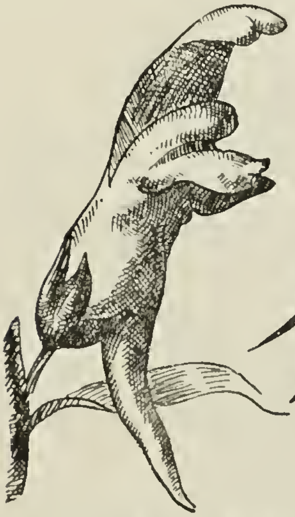


Fig 369.—Yellow Toadflax.

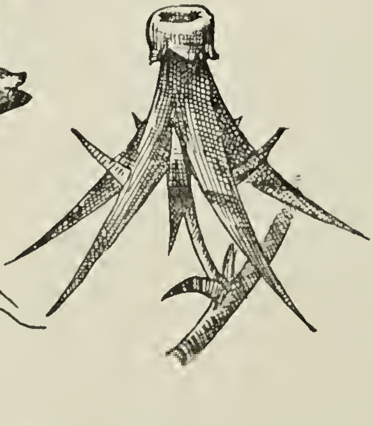


Fig. 370.—A peloric flower of same.

This last statement is evidently a mistake. Mr. Knapp is probably referring to the neat round hole which is made by certain short-tongued bees *from without*, to enable them to reach the nectar and nullify the flower's precautions for their exclusion.

The wood-ant (*Formica rufa*) is a common plunderer of the flower, but, as already remarked, its chief *fertilisers* are humble-bees, which do no injury to their host, and leave by the door they enter at. "It is most interesting to observe," writes Kerner, "how a humble-bee buzzes about till it alights on the two knobs of the lower lip, and then, having opened the mouth by means of hinges on either side of the corolla, suddenly disappears into the cavity of the flower to fetch honey. In the Calceolarias," continues this writer, "the phenomenon is even more remarkable. The humble-bee sits on the inflated, slipper-like lower lip (fig. 375), and opens the mouth by a light pressure against the upper lip. Then a nectary, hitherto hidden in the slipper-like cavity, comes to light, flap-like, and amply provided with honey. This nectary is presented to the humble-bee just like a spoon as it sits on the lower lip. Directly the bee goes, the lower lip snaps to, and the nectary disappears from view." The Calceolarias, indeed, bring before us a new form of corolla, the *calceolate*, or slipper-shaped. They offer good illustrations of special thickenings in parts of flowers where the strain caused by insects is most felt. *Calceolaria Pavonii* is a striking example of this (fig. 374). Along each of the upper edges of the curved basal part of this flower—

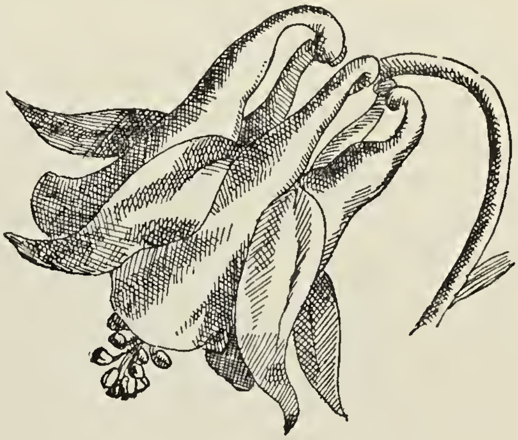


Fig. 371.—Flower of Columbine.

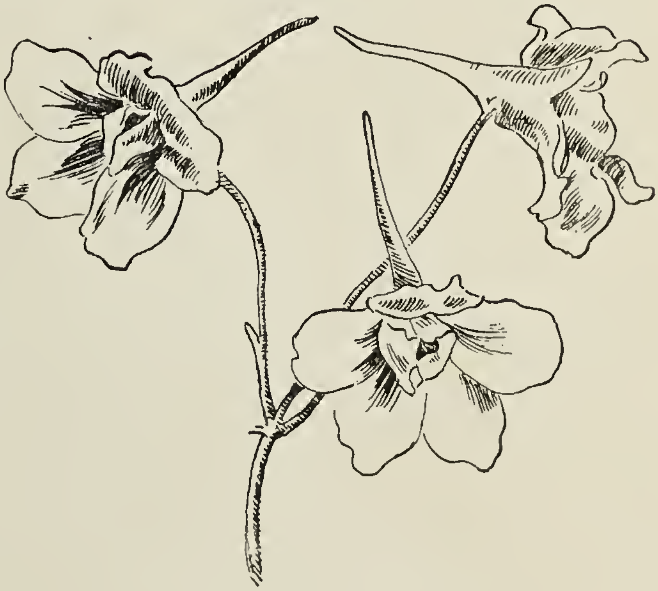


Fig. 372.—Flowers of Aquilegia.

that part which carries the inflated end upon which the bee stands — there is a thickened ridge (*a*), and this gives wonderful strength to the support and prevents injury when the bee alights.

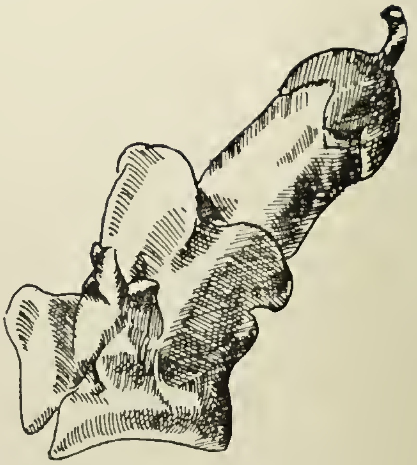


Fig. 373.—Personate corolla of Snapdragon.

The very cohesion of the petals, in this as in all flowers where cohesion takes place, is also a source of strength; and swellings and hollow projections in particular places may subserve a similar end. The bulge in the tubular part of the Foxglove flower is evidently for this purpose; as in all probability are the curious projections in many kinds of *gibbous* or pouched corollas. The Great Wild Valerian (*V. officinalis*, fig. 376) offers a good example of this form. The small pouch or hump in this particular flower is the nectary, in the green fleshy floor of which the honey is secreted. As the pouch is short and easily accessible, the flower is largely patronised by insects, and cross-fertilisation regularly takes place.

Returning for a moment to the simpler kinds of gamopetalous flowers, notice a familiar example of the *globose* corolla (fig. 377). It is the Figwort (*Scrophularia nodosa*), which blooms in moist places from July to September. Perhaps it is not the best instance that might be given of the globular form—some of the Heaths (*Erica*) would better fulfil the requirements of the name—but we have adopted it because the flower is one of those which, unlike the flowers which we have been hitherto considering, lay themselves out for fertilisation by insects with *short* probosces. Wasps are its chief visitors, and easily reach down to the honey at the base of the corolla; while long-tongued insects, such as humble-bees and butterflies, avoid the flower altogether.

The globular form often merges imperceptibly into the *urceolate*, or urn-shaped—indeed, a single spray of Heath will sometimes show both forms (figs. 378-380)—but a better example of an urceolate flower than the Heath is the Whortleberry (*Vaccinium Myrtillus*), the corolla of which might have furnished designs to the sepulchral-urn-makers of ancient Etruria (fig. 381). As a rule, only insects with a proboscis long enough to reach from the exterior to the base of the corolla, where the honey is lodged, can reach that coveted treasure, as the opening is too narrow to admit the bodies or even the heads of the majority of nectar-sipping insects.

A curious and exceptional form of corolla is the mitræform or mitre-shaped (fig. 382). In occurs in the Grape Vine (*Vitis vinifera*). The five petals, which are coherent at their tips, form a dome-like covering to the stamens and ovary; but they are green and insignificant, and hardly distinguishable from the foliage; on which account they are valueless as insect lures. The plant, therefore, does well in getting rid of them as soon as possible, and this is effected in a beautiful manner. The petals become detached at their base, and curl up spirally—that is to say, towards their common point of attachment at the apex of the flower; and in this condition they remain till, by the expanding of the stamens, they are thrown off completely.

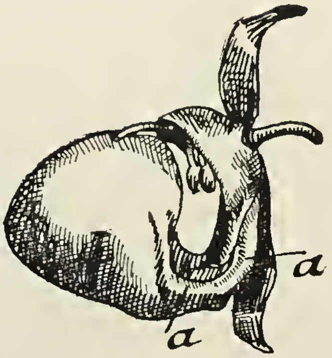


Fig. 374.—Calceolate flower of *Calceolaria Pavonii.* (*a*) Thickened ridge.

A more interesting, because more intricate, form of irregular flower than any which we have yet considered is that which constitutes the characteristic feature of the well-known and extensive sub-order of *Leguminosæ* to which the Pea and Bean belong — namely, *Papilionaceæ.* This name at once suggests the form of the corolla, which Tournefort and Ray, and the early botanists generally, conceived to bear a resemblance to a butterfly with expanded wings. *Papilio* is the Latin word for "butterfly," and hence the corolla came to be called *papilionaceous* and the sub-order *Papilionaceæ.* But it was reserved for a modern philosopher to advance the startling suggestion that possibly the first butterflies were flowers "which got loose from their stalks and flew away"! Papilionaceous flowers are fertilised almost exclusively by bees, to which the several parts of the corolla bear the most evident relation. The reproductive organs (stamens and pistil) are contained in the two inferior petals (fig. 382), which cohere to form the keel or *carina* (*c c*), the latter an excellent contrivance for protecting the anthers from pollen-feeding insects and from rain. The lateral petals (*a a*)—known as the wings or *alæ*—besides affording a platform for bees, serve as a lever to depress the keel, as well as to bring it back to its place after depression, if repeated insect-visits are necessary for fertilisation. Lastly, the large posterior petal, which is known as the standard

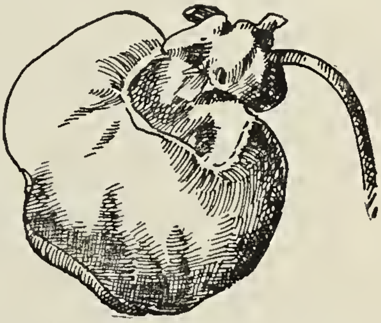


Fig. 375.—Calceolate corolla of a Calceolaria.

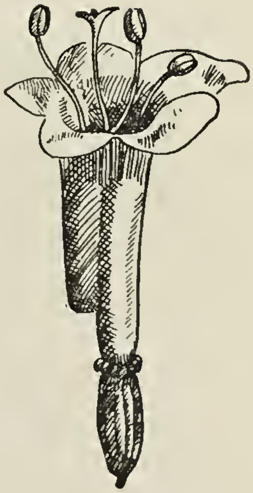


Fig. 376.—Flower of *Valeriana officinalis* with gibbous corolla.

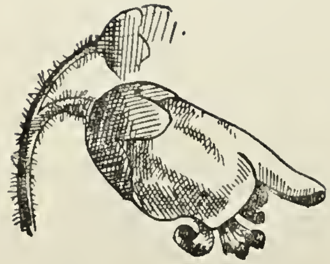
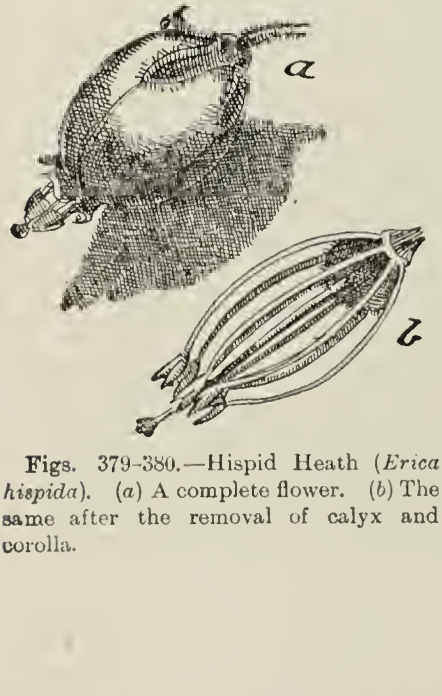


Fig. 377.—Flower of Knotted Figwort with sub-globose corolla.

or *vexillum* (*v*), gives conspicuousness to the flower, as well as closes the entrance to the nectary *from behind*, so that insects seeking honey must sit either on the keel or wings.

We must not conclude these remarks upon the forms of calyxes and corollas without some reference to *composite* flowers. A composite flower is really a number of *florets* crowded together on a single base or *receptacle*, such as we find, for instance, in the flower-head (capitulum) of a Daisy (*Bellis perennis*) or Dandelion (*Taraxacum officinale*). We have chosen for illustration the flower-head of a Chrysanthemum (*C. carinatum*), the florets of which are more easily distinguished than are those of the commoner flowers above named. What you see (fig. 385) is a section, the flower-head having been cut through longitudinally in order to exhibit a perfect row of the disc florets. Each of these florets, which you will observe are tubular in form, is a perfect flower, capable of setting seed. The corolla-tube covers at its base the ovary (fig. 386, *ov*), and hides from view the greater part of the styles, the only portion visible being the end which bears the branched stigmas (*st*). Surrounding the flower-head are some florets of another kind, each of the so-called petals being a female flower, or, in scientific parlance, a *rayed* floret with *ligulate* (*i.e.*, strap-shaped) corolla (figs. 387, 388).

One of the great purposes effected by the massing together of the florets in composite flowers is admirably suggested by Kerner in his remarks upon the taking up of



Figs. 379-380.—Hispid Heath (*Erica hispida*). (*a*) A complete flower. (*b*) The same after the removal of calyx and corolla.

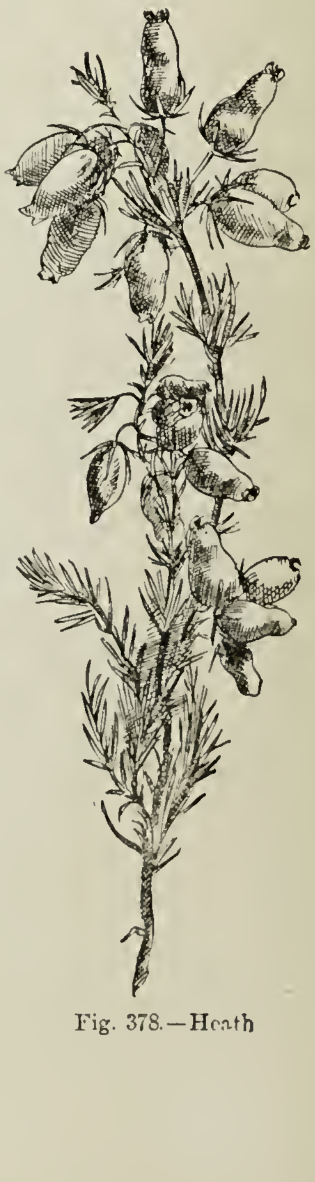


Fig. 378.—Heath

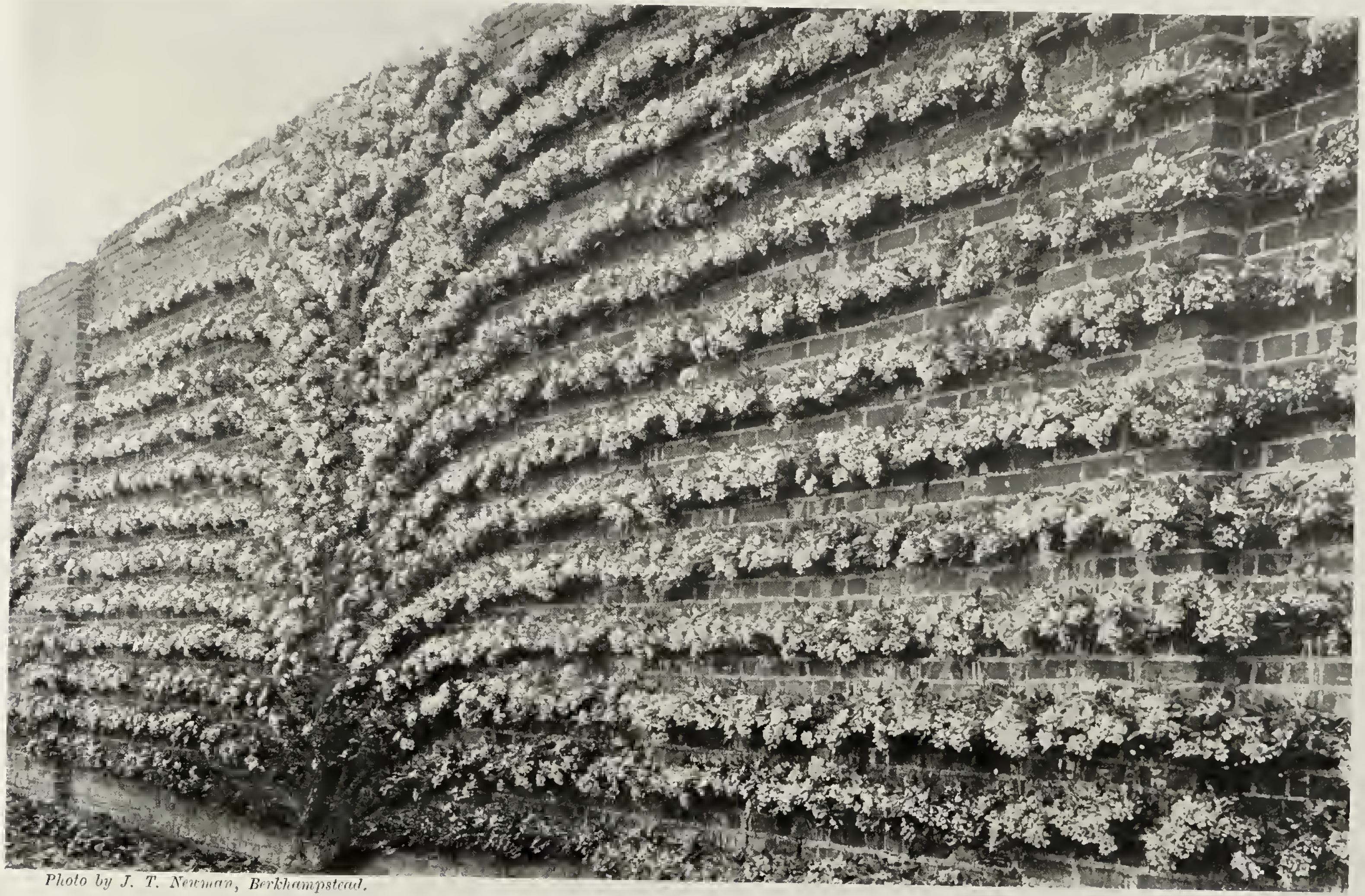


Photo by J. T. Newman, Berkhampstead.

Pear Tree (*Pyrus communis*) laden with Blossom.

An extraordinarily prolific specimen growing in a country garden

Plate XXVIII.

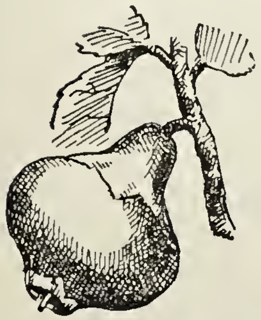


Fig. 381.- Flowers of Whortleberry with urceolate corolla.

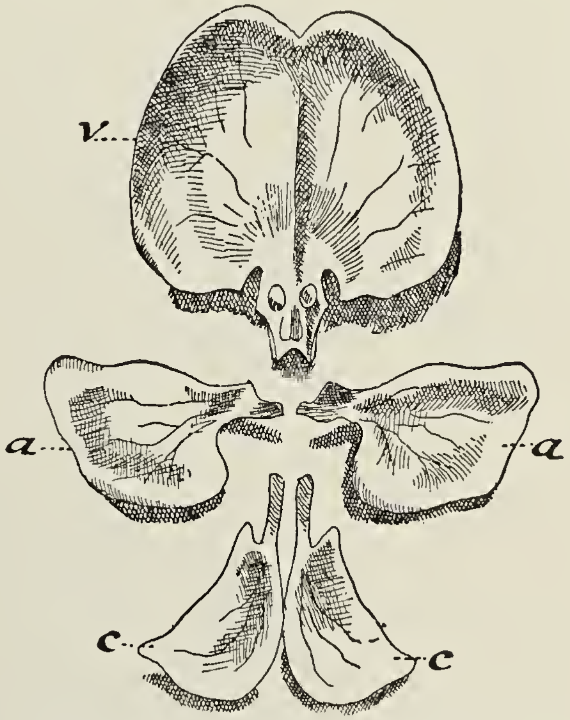


Fig. 382.—Corolla of a papilionaceous flower laid open. (*v*) Vexillum or standard. (*a a*) Alæ or wings. (*c c*) Carina or keel.

pollen by insects. "Great quantities of pollen," he tells us, "adhere to the under parts of insects in the case of composite inflorescences. Shortly after the opening of the corollas the style bearing an external load of pollen is exserted from each of the little tubular and ligulate florets composing the capitulum in this group, and, owing to the fact that large numbers of these florets invariably open simultaneously, numbers of styles laden with pollen project close together from the discoid head. A largish insect settling on a capitulum may therefore be dusted with the pollen of numerous florets at once. As he twists and turns about on the disc of the inflorescence, inserting his proboscis into one floret after another, a lot more pollen is brushed off on to the under surface of his body, and he finally leaves the capitulum with an abundant freight." Darwin observes that the ray-florets of composite flowers protect the florets of the disc by folding inwards at night and during rainy weather. "Moreover," says he, "they often contain matter which is excessively poisonous to insects, as may be seen in their use for flea-powder; and in the case of *Pyrethrum*, M. Belhomme has shown that the ray-florets are more poisonous than the disc-florets in the ratio of about three to two. We may therefore believe that the ray-florets are useful in protecting the florets from being gnawed by insects."

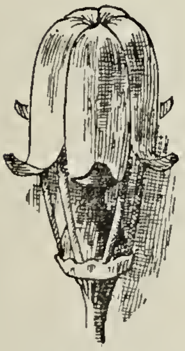


Fig. 383.—Flower of Grape Vine with mitræform corolla.

Composite flowers constitute the largest order in the Vegetable Kingdom (*Compositæ*), about one-tenth of the Flowering Plants belonging to it. A characteristic of this order not yet touched upon, yet intimately connected with our present subject, is the production of a *pappus* from the limb of the calyx. Two forms of such hairy crowns, the *sessile* and the *stipitate*, are shown in figs. 619 and 620. The formation of a pappus is looked upon as a modification of the calyx. It is made subservient, as every child knows, to the scattering of the fruit.

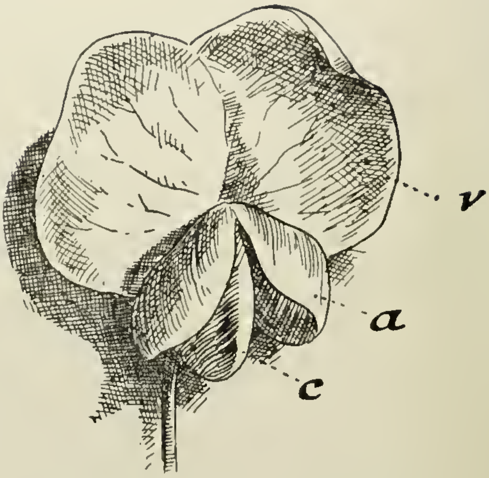


Fig. 384.—A papilionaceous flower.

In not a few flowers the corolla is provided with a supplementary organ known as the *corona* or crown, sometimes called the *paracorolla*, which in some cases is small and inconspicuous, and in others large enough to add materially to the beauty or singularity of the plant. A corona is one of the distinguishing marks of the large genus *Narcissus*, to which our own Wild Daffodil (*Narcissus Pseudo-Narcissus*) belongs. In a less exaggerated form this "corona" will be found also in the Forget-me-not (*Myosotis*) and *Primula*. Henslow (*Journal of the Linnæan Society*, vol. xvi., 1877) regards it as a development of a fold in the

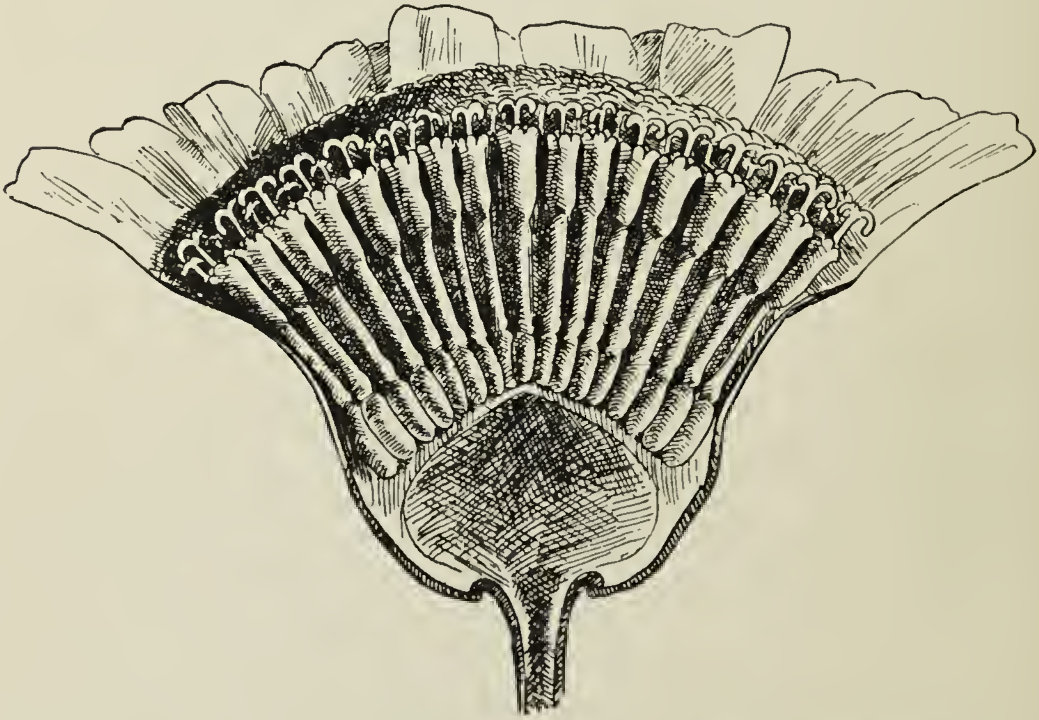


Fig. 385.—Section through a flower-head (capitulum) *of Chrysanthemum carinatum.*

inner epidermis of the corolla. In the well-known Poet's Narcissus (*N. poëticus*, fig. 390) the white crown is surrounded by a cinnabar-red border, which is probably a means of attracting insects; and in most species of the family this organ is either delicately marked or the whole of the corona is of a deeper colour than the rest of the perianth. The crown of the Passion-flower (*Passiflora*), which in some species is single, in others double, is split up into narrow threads (fig. 431), which Fritz Müller, a naturalist who has given much attention to the mechanism of floral organs, believes to be of service in detaining small insects in the lowest chamber of the flower, and keeping them caged for humming-birds, the chief fertilisers of many species of *Passifloræ*.

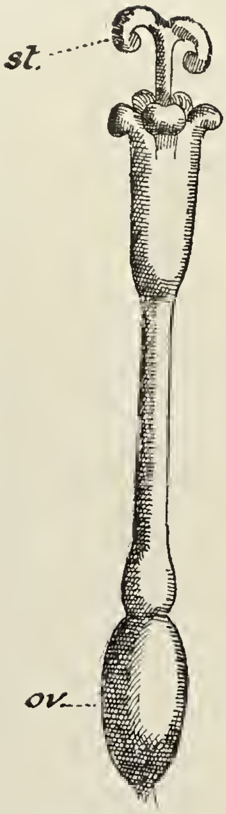


Fig. 386.—A disc-floret of same. (*ov*) Ovary. (*st*) Stigma of pistil.

In the White Dead-nettle (*Lamium album*) there is a circle of hairs in the narrow part of the corolla-tube, near the base; and it serves the purpose of excluding flies and small bees from the nectar, these being useless to the plant. The corona of our beautiful bog-flower, Grass of Parnassus (*Parnassia palustris*), is very interesting. It consists of five scales (the nectaries) terminating in hairs, each of which is surmounted by a yellow glandular body, which has all the appearance of a drop of fluid. Even flies are deceived by these shining knobs, mistaking them for drops of honey; but they are dry as dead sticks, and yield their visitors absolutely nothing. Other kinds of corona might be mentioned, but these are the chief and most characteristic forms, and it is manifestly impossible to speak of all in a chapter so discursive.

We come now to the stamens or male organs, which are known collectively as the *andrœcium*. The forms of these, like the forms of the calyx and corolla, vary considerably, but we need trouble the reader with very few hard names. It is certainly im-

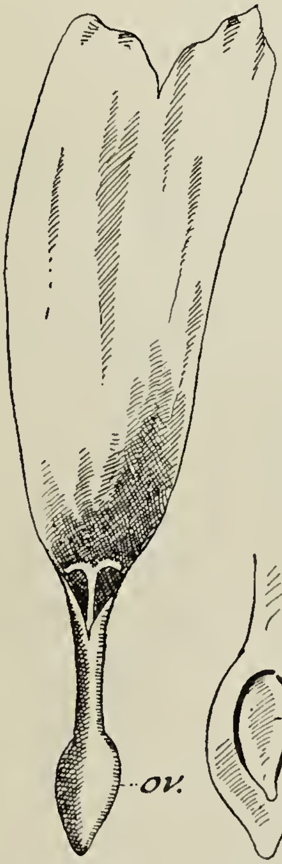


Fig. 387.—A ray-floret of same. (*ov*) Ovary.

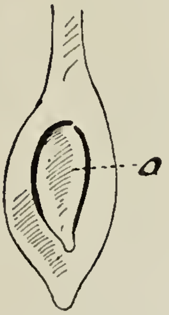


Fig. 388.—An ovary of same in section. (*o*) Ovule.

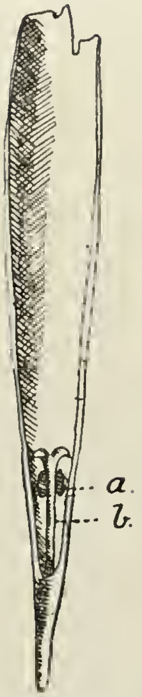


Fig. 389.—Longitudinal section through one of the tubular disc-florets of *Pyrethrum*. (*a*) Anther-lobes. (*b*) Pistil.

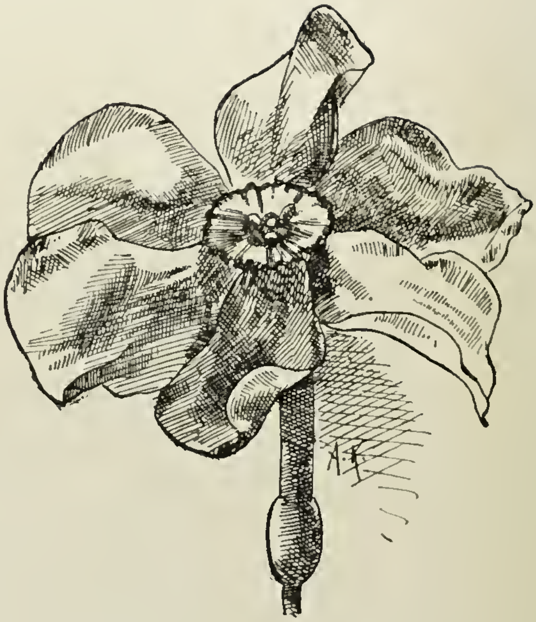


Fig. 390.—Flower of Poet's Narcissus.

portant to remember what has been already said about the stamens in connection with cohesion and adhesion, but beyond this there is really little to be acquired.

Nevertheless, it is instructive to notice the diversities of form and mechanism which the andrœcium presents, and which, we would add, are usually connected with that most important function, the scattering of the fertilising meal or pollen. Thus, in the Grasses (*Gramineæ*), which are fertilised by the wind, the anthers swing loosely on their connectives, and so assist the wind in its useful labour — they are *versatile*; while in certain species of Sage (*Salvia*) the connective forms a curved bar or lever, and runs trans-

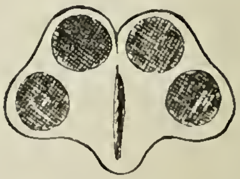
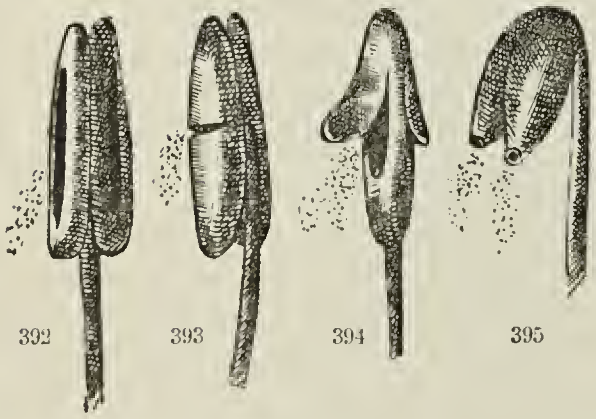


Fig. 391.—Cross-section of anther of Lily. The shaded parts are the pollen-sacs.



Figs. 392-395.—Dehiscence of anthers.
392. Longitudinal. 393. Transverse. 394. Valvular. 395. Porous.

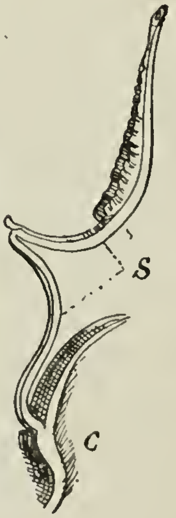


Fig. 396.—Stamen of *Melastoma malabathricum*. (*c*) Portion of calyx. (*s*) Stamen.

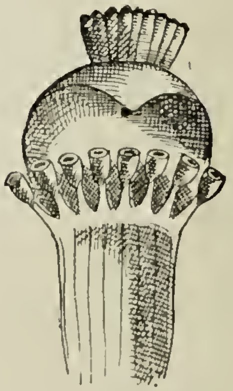


Fig. 397.—Flower of a species of Milkwort (*Polygala erioptera*) cut open to show the stamens.

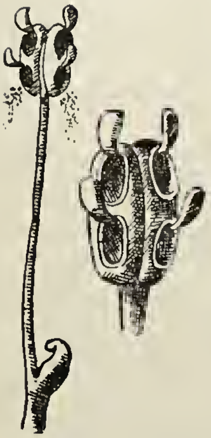


Fig. 398.—Stamen and anther of *Litsæa Baueri* with recurved valves.

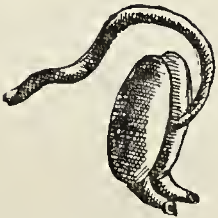


Fig. 399.—Stamen of *Pyrola uniflora*.

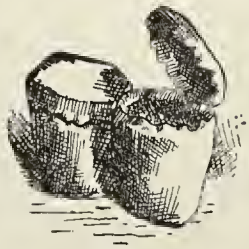


Fig. 400.—Stamens of *Garcinia Morella*.

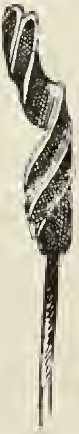


Fig. 401.—Stamen of Centaury (*Erythræa Centaurium*).

versely to the filament, to which it is attached by a movable joint, the purpose of which will be explained hereafter. From some stamens the filament is entirely absent, and the anthers, which are then described as *sessile*, may be attached either to the petal of the flower, as in Vervain (*Verbena*), or to some part of the pistil, as in the Birthwort (*Aristolochia*). In a large number of cases the connective is perfectly continuous with—or, in other words, is a direct prolongation of—the filament, the point of attachment of the anthers being immediately upon the top of the filament; but far more frequently the latter is prolonged up behind the anther-lobes (figs. 428, 429). The terms *basifixed* or *innate* and *dorsifixed* or *adnate* are applied respectively to these two kinds of attachment.

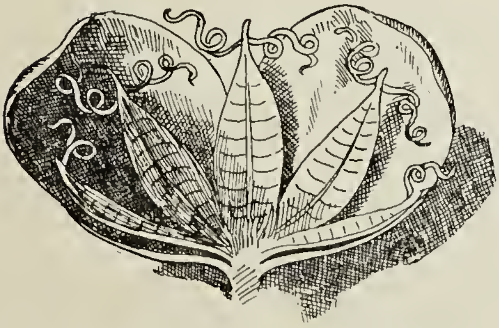


Fig. 402.—Section through a male flower of *Acalypha phleoides*, showing worm-shaped anther-cells.

When the *face* of the anther—or, in other words, the surface opposed to that to which the connective is attached—is turned towards the pistil of the flower, the stamens are said to be *introrse*; when. on the other hand, the face is turned towards the petals, the stamens are *extrorse*. The *direction* in which the anthers *dehisce*—that is, discharge their pollen—is thus largely dependent upon the position of the stamens—a fact to be carefully noted. The *mode* of dehiscence is chiefly determined by the nature of the apertures through which the pollen escapes. When, as is most

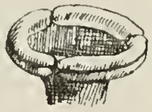


Fig. 403.—Curved anthers of *Cyclanthera*.

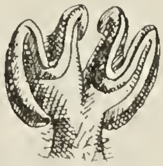


Fig. 404.—Undulating anthers of *Cucumis*.

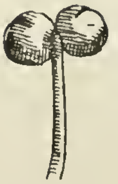


Fig. 405.—Globular anther-lobes of *Excœcaria*.

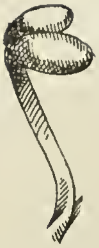


Fig. 406.—Oval ditto of Foxglove.

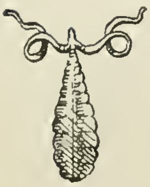


Fig. 407.—Linear ditto of *Acalypha*.

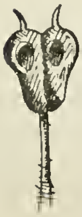


Fig. 408.—Pear-shaped ditto of *Arctostaphylos alpina*.

frequently the case, the anther opens by narrow upright slits running from top to bottom of the lobes, the dehiscence is said to be *longitudinal*; when the lobes are slit crosswise, the dehiscence is *transverse* (figs. 392, 393). In not a few flowers the lobal orifices are wide and concealed by delicate valves or flaps, which lift up like a trap-door at the moment of shedding the pollen. This is *valvular* dehiscence (fig. 394). When, as in the case of the Potato (*Solanum tuberosum*) and Common Whortleberry (*Vaccinium Myrtillus*), the dehiscence is effected by minute fissures or pores at the tips of the lobes, we speak of it as *porous* (fig. 395).

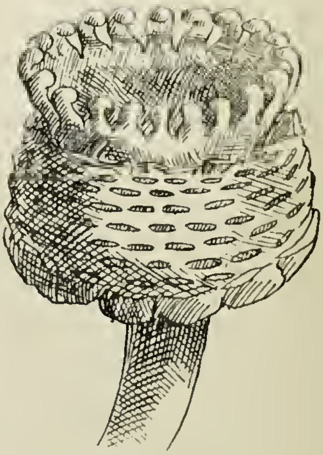


Fig. 410.—Pistil of White Water-lily with coronate stigma.

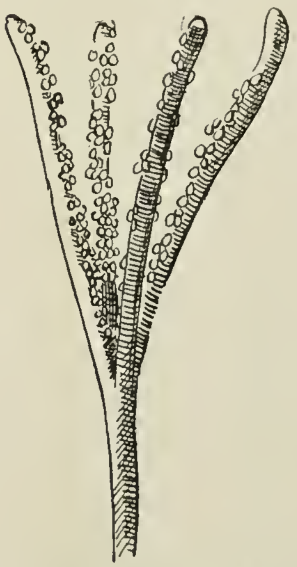


Fig. 409.—Stigma of *Plumbago capensis* with pollen-grains.

The forms of many stamens, as already intimated, are exceedingly curious; and the subject offers an inviting field to the young and ardent observer. No plants, perhaps, exhibit more singularity in this respect than those belonging to the *Melastoma* series (order *Melastomaceæ*, fig. 396) and to the various genera of *Anonaceæ*; though, indeed, the male organs of many of our commonest wild-flowers are extremely remarkable. In some stamens the filaments are slender along their whole length, as in the Willow-herb (*Epilobium*, fig. 417); or they taper gradually from the base, as in *Lapageria*, while in others

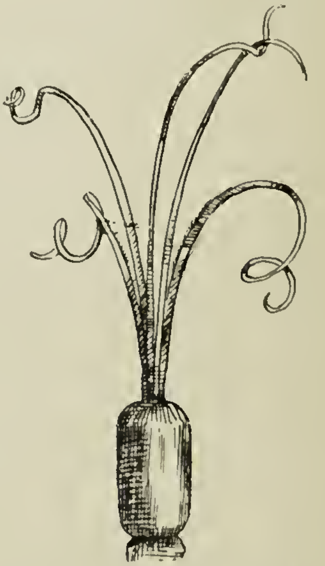


Fig. 411.—Five-styled ovary of White Campion (*Lychnis vespertina*).

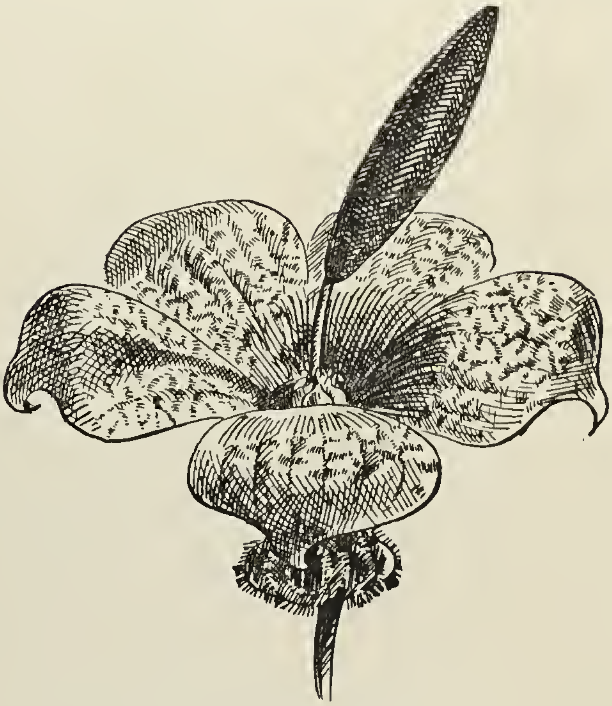


Fig. 412.—Flower of *Campanula macrostyla.*

they are stunted and club-shaped, as in *Calceolaria* (fig. 420), or flattened and petaloid, as in the white Water-lily (*Nymphæa alba*, fig. 410).

The anthers, too, assume the most various shapes—globular and oval, pear-shaped and worm-shaped, curved and undulating (the latter a form which reminds one of the convolutions of the human brain), pitcher-like and box-shaped, etc., etc. (figs. 402-408); while many of these forms are rendered still more striking by the presence of appendages in the shape of hairs, tubes, fleshy hooks, leaf-like expansions, coloured bladders for attracting insects, feathery growths, and other singular contrivances whose name is Legion. Such appendages are usually prolongations of the connective. The almost naked stamens of *Leitneria floridana*, a shrub with willow-like leaves inhabiting the marshes of the southern United States, are seated upon bracts, furnished with hairy appendages, which give a curious flocculent appearance to the whole inflorescence (fig. 419).

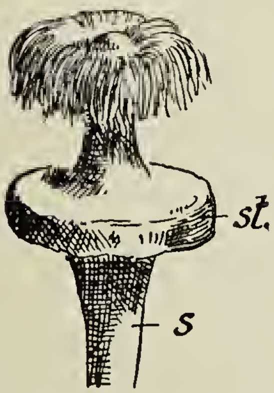


Fig. 413.—Style (*s*) and stigma (*st*) of Periwinkle (*Vinca major*).

We will close this account with a few remarks on the forms of the *gynœcium*, or pistil. Naturally and necessarily the form varies according as the pistil is simple or compound, apocarpous or syncarpous; yet

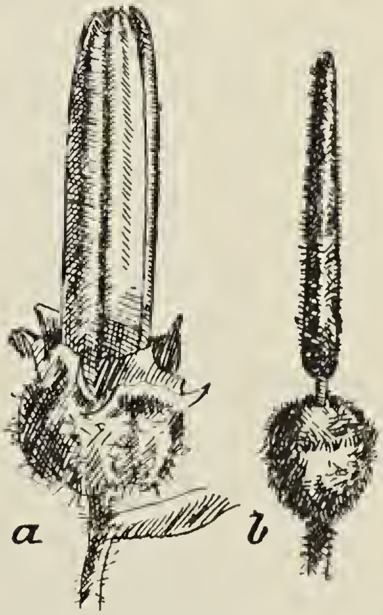


Fig. 414.—Stamens (*a*) of young bud of Canterbury Bell (*Campanula Medium*). (*b*) Pistil of same.

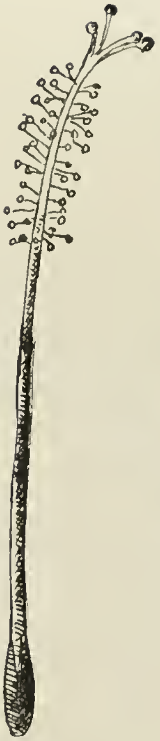


Fig. 415.—Stamens and pistil of *Hibiscus Rosa-sinensis.*

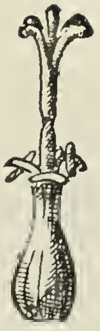


Fig. 416.—Stamens and pistil of one of the Cranes-bills (*Geranium*).

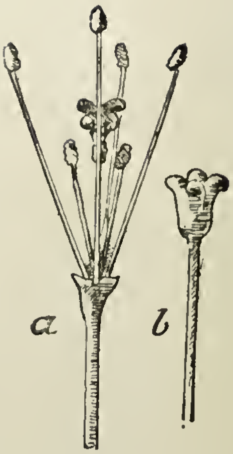


Fig. 417.—(*a*) Stamens and pistil of a species of Willow-herb (*Epilobium montanum*). (*b*) Style and stigma of the pistil.

are there other causes of variation. Morphologically considered, there is a kind of analogy between the andrœcium and the gynœcium — between the male and female organs of a plant. A stamen or male organ consists, normally speaking, of three parts—the filament, the connective, and the anther; a pistil also consists of three parts—the ovary, the style, and the stigma. And just as the stamen assumes different forms according as its filament is long or short, its connective with or without appendage, its anther-lobes globular or oval, pear-shaped or linear, etc., etc., so the form of the pistil varies in accordance with analogous diversities in the ovary, style, and stigma—the last two more particularly. Thus the style may be curved or straight, branched or unbranched, hairy or smooth; and the general form of the pistil will, of course, vary in relation to these several points. The mode of insertion of the style is also a cause of variation. It may spring either from the top of the ovary, when it is *terminal*; or from the side, when it is *lateral*; or from the base, when it is *basilar.* Sometimes it is entirely absent, and then the stigma rests upon the ovary, and is said to be *sessile.*

The style, indeed, is not an essential part of the pistil; the stigma is. It will be remembered that the latter is the organ which serves for the detention of the pollen-grains. Nature, as might be

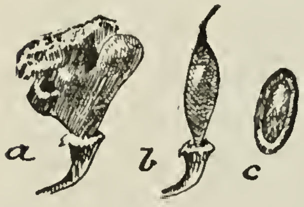


Fig. 418.—Essential organs of Garden Balsam (*Impatiens Balsamina*). (*a*) The stamens, covering the pistil, and exposing their pollen for bee visitors. (*b*) Pistil. (*c*) A pollen-grain.

Fig. 419.—Male flower of *Leitneria floridana.*

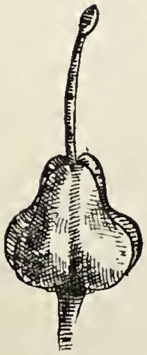


Fig. 420.—Pistil of *Calceolaria.*

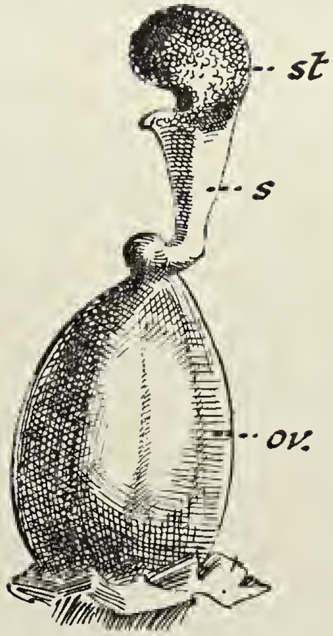


Fig. 421.—Pistil of Pansy (*Viola tricolor*). (*st*) Stigma. (*s*) Style. (*ov*) Ovary.

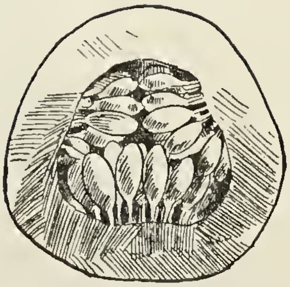


Fig. 422.—Transverse section of young ovary of Pansy flower.

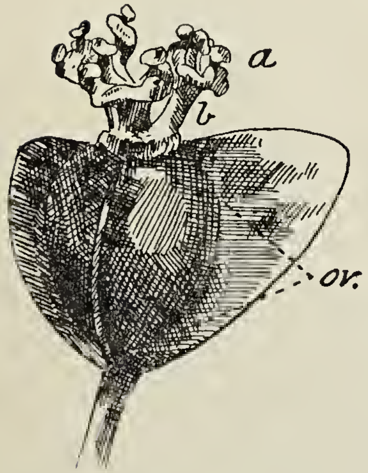


Fig. 423.—Pistil of *Begonia.* (*o*) Ovary. (*a*) Stigma. (*b*) Style.

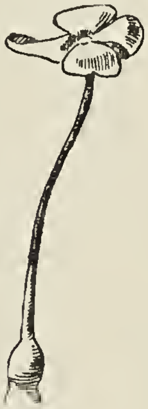


Fig. 425.—Ovary of *Clarkia* with rayed stigma.

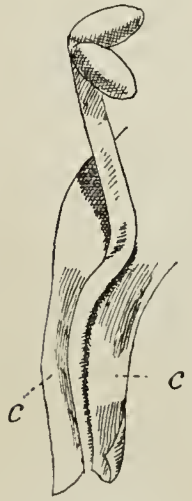


Fig. 424.—Stamen of Foxglove (*Digitalis*). (*c c*) Portion of corolla.

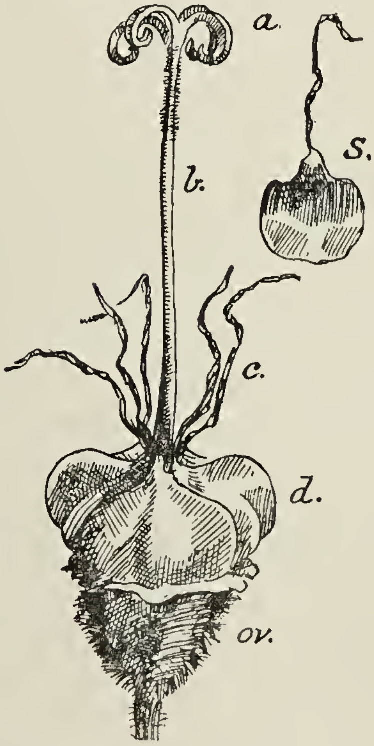


Fig. 426.—Pistil of Canterbury Bell (*Campanula Medium*). (*a*) Stigma. (*b*) Style. (*c*) Withered filaments of stamens. (*d*) Dilated fleshy bases of stamens covering nectary. (*ov*) Ovary. (*s*) One of the stamens detached.

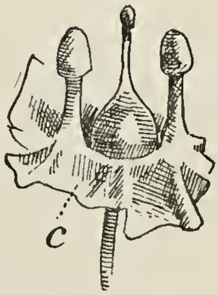


Fig. 427.—Stamens and pistil of *Calceolaria.* (*c*) Portion of corolla.

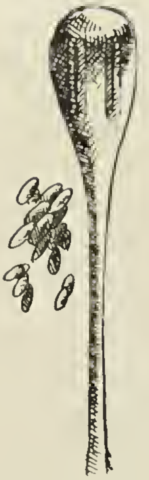


Fig. 428.—Basifixed anther of a *Begonia* with pollen-grains.

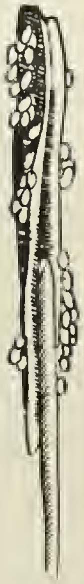


Fig. 429.—Dorsifixed anther of *Plumbago*.

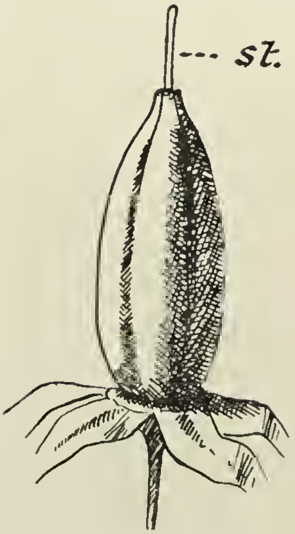


Fig. 430.—Stamens of Woody Nightshade. (*st*) Style or pistil.

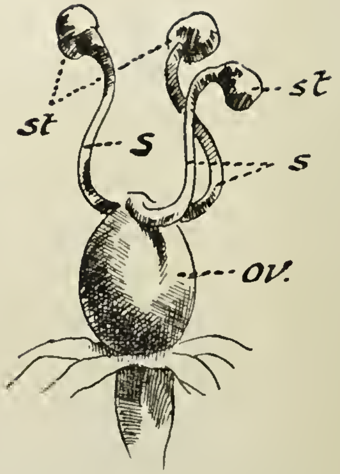


Fig. 431.—Pistil of Passion-flower. (*st*) Stigma. (*s*) Style. (*ov*) Ovary.

guessed, has all sorts of devices for facilitating this object, and hence the multitudinous forms of stigma—*peltate*, *plumose*, *penicillate*, *petaloid*, etc.—which the pistils of flowers present (figs. 420, 421, 423, 425–433). The stigma, says Kerner, "is expanded in only a few families of plants, amongst which the Irises are the best known. It has to receive and hold the pollen-grains, and its form varies according as to whether these are carried by the wind as flower-dust or are brought to the flowers by insects in cohering masses. In the former case the stigmas are brush-like or feathery, often extended like a cobweb or spread out like a plume; in the latter case, projecting papillæ, knobs, ridges, and bands are found on them, against

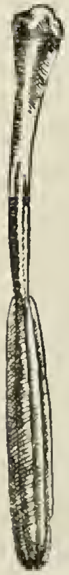


Fig. 432.—Pistil of Japan Lily (*Lilium speciosum*).

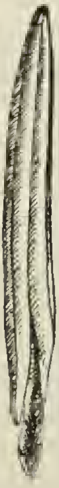


Fig. 433.—Stamen of same.

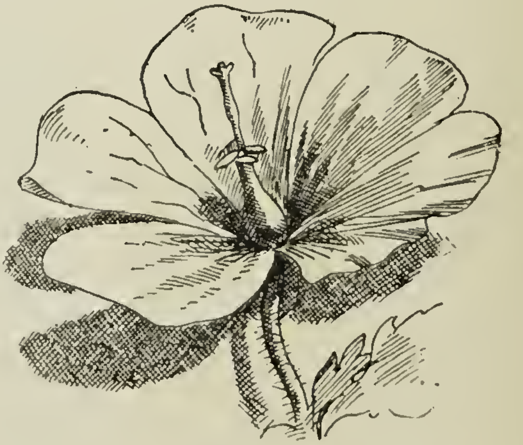


Fig. 434.—Hypogynous flower of *Geranium*.

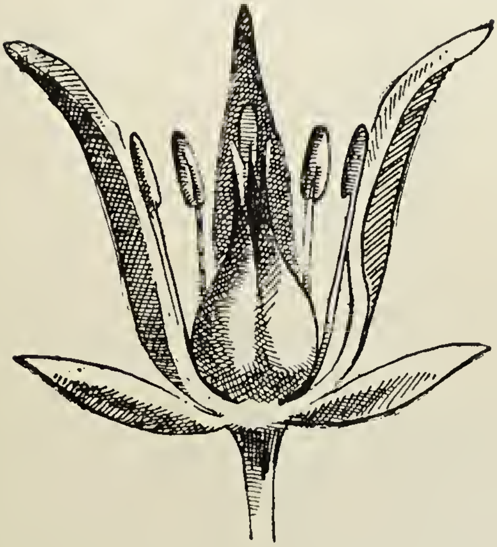


Fig. 435.—Section through the hypogynous flower of *Echeveria*.

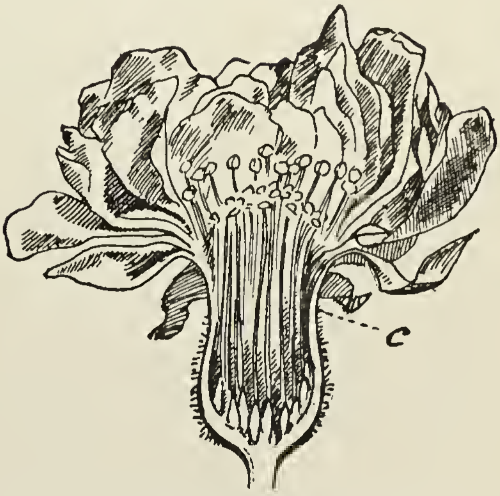


Fig. 436.—Section through perigynous flower of Rose, showing tubular receptacle (*c*).

which the insects knock off the pollen as they enter the flower." We need hardly add that these stigmatic roughnesses are, like the pollen itself, extremely minute—invisible, indeed, to the naked eye, and often requiring a high power of the microscope to distinguish them.

It should be added that the relative position of the calyx, corolla, and stamens to the pistil is a matter of considerable importance. Observe the flower of a Geranium (fig. 434). Here the ovary is *superior* to the other floral organs, which are attached to or below its base. Such a flower is termed *hypogynous*, from the Greek words *hupo*, under, and

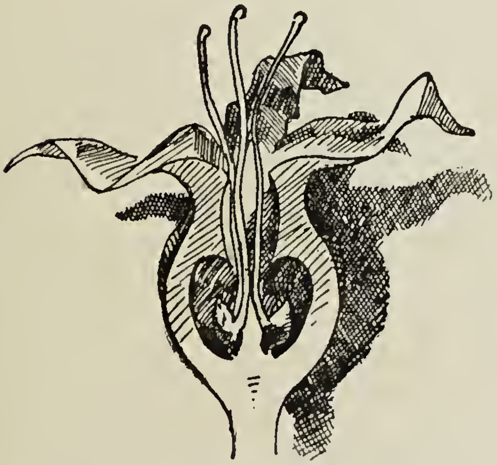


Fig. 437.—Section through perigynous flower of Apple after the corolla has fallen.

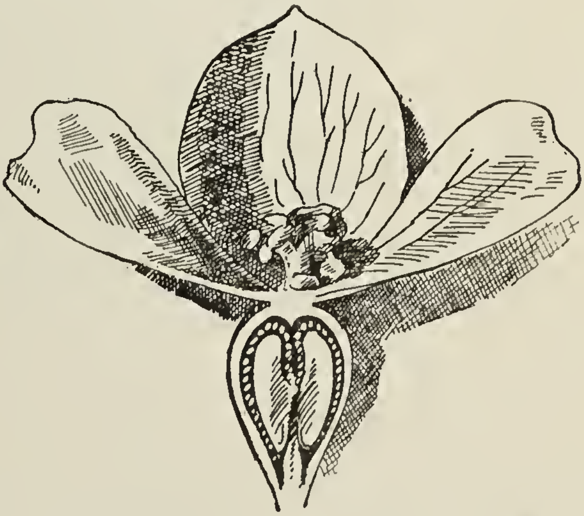


Fig. 438.—Section through epigynous flower of *Begonia*.

gunē, a woman. The Buttercup and Echeveria (fig. 435) are other examples of hypogynous flowers. Compare these with the sections of the flowers of Rose and Apple (figs. 436, 437), in which, by the more vigorous growth of the axes, a tube is formed around the carpels, and the stamens and perianth are raised so that they stand on the apex of the rim of the tube. The Rose and Apple are *perigynous* flowers (Greek *peri*, around, and *gunē*).* In the Begonia (fig. 438) and Carrot (fig. 344) we have a third mode of insertion. In both cases the ovaries are situated below the perianth—they are inferior; whilst the flowers as a whole are described as epigynous (Greek *epi*, upon, and *gunē*).

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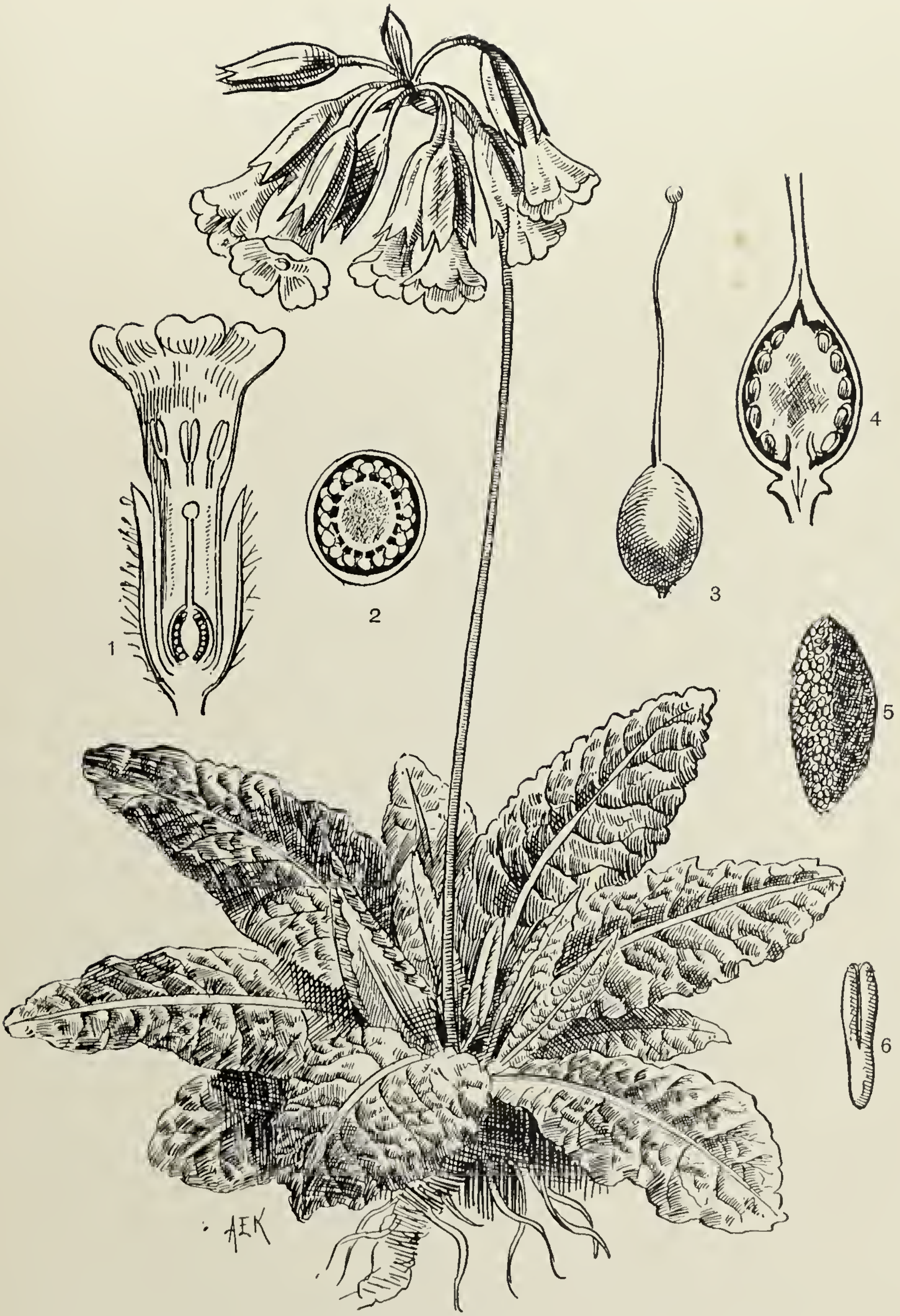
* In the case of the Rose, each of the carpels has a distinct ovary; in the Apple the ovary fills the whole cavity of the tube, with the inner wall of which it is fused. The immature "pips" are ovules, not ovaries.



Cowslip (*Primula veris*).

In the centre is shown the complete plant, with its rosette of leaves and umbel of drooping flowers. Proceeding from left to right we have: (1) a longitudinal section through a single flower. (2) Transverse section of ovary. (3) Pistil. (4) Longitudinal section of ovary. (5) Seed. (6) Embryo.

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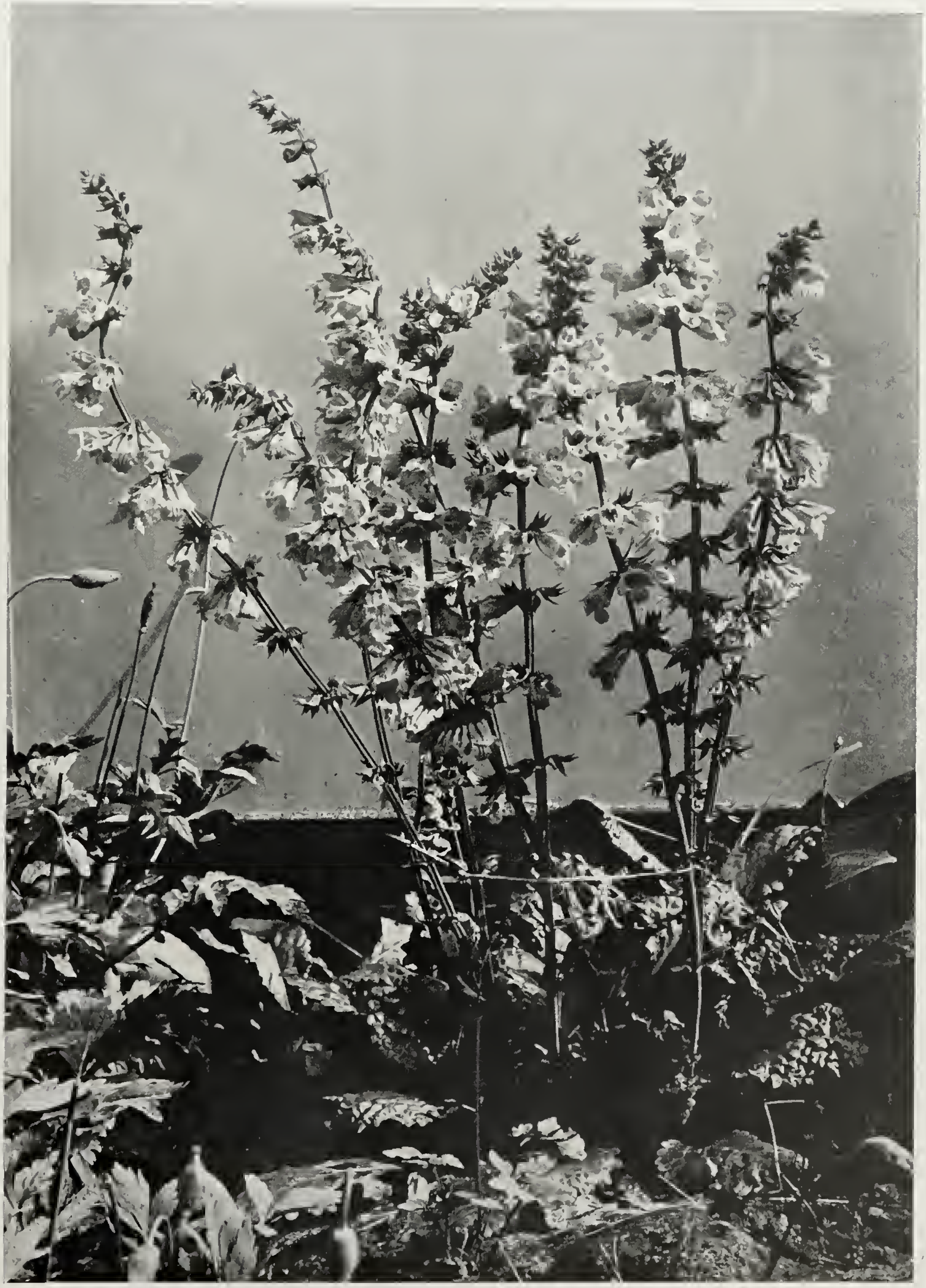

Photo by Walter Rossiter, Bath.

Horminum pyrenaicum.

An interesting genus, containing only one species, of the order *Labiatæ*; the purple flowers bear in the lower part of the corolla-tube palisades of elastic hairs to protect the honey from unbidden guests.

PLATE XXXII.

CHAPTER XI

THE WELCOME OF THE FLOWERS; WITH SOME PRELIMINARY REMARKS ON EXCLUSIVENESS

These have their sexes! and when summer shines,
The bee transports the fertilising meal
From flower to flower, and e'en the breathing air
Wafts the rich prize to its appointed use.
COWPER.

THE important part which insects and other external agents play in the fertilisation of flowers was indirectly alluded to in the last chapter, and we propose now to follow out this interesting subject in some detail.

The insects which visit flowers may, for popular purposes, be divided into two classes—*bidden and unbidden guests*; the former being useful to the plant, the latter useless. It may be added that an insect which is a welcome visitor to one kind of flower may be an unwelcome visitor to another; so that the terms "bidden" and "unbidden" have only a relative significance. Incidental allusion has been already made to some of the contrivances in plants for the exclusion of certain visitors; we may now consider a few more of these contrivances, with special reference to the flower.

Fig. 439.—Part of the flowering branch of a Gentian (*Gentiana affinis*).

Of the necessity of excluding various kinds of insects from certain flowers there can be no question. "Guests might come," says Dr. Ogle, in his amusing preface to Kerner's famous little book, *Flowers and their Unbidden Guests*, "who were not of sufficient importance, and the banquet [whether of nectar or pollen] be wasted on them; for it is only when insects have a certain shape, size, or weight that she requires their visits, and can use them profitably for her purposes. . . . All insignificant and unremunerative visitors, all such, moreover, as would creep in by the back entrance, must be kept out."

Thus the opposite leaves of a plant may form a kind of collar, or series of collars, to the inflorescence, insurmountable to wingless insects from below, as is the case in many Gentians (fig. 439); or even the stipules and alternate leaves may act in the same way, as in the Common Pear and Thorowwax respectively.

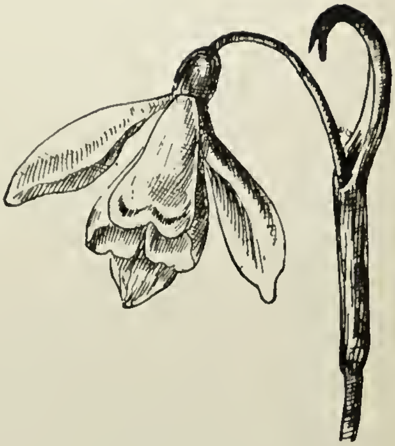
Fig. 440.—Snowdrop.

How excellently, again, is a *pendulous* flower adapted for the exclusion of small creeping insects! Take the Snowdrop (*Galanthus nivalis*, fig. 440). Where is the ant that could get inside the hanging flowers of this February maid? Their slippery curved walks would defy all its efforts; and, as a matter of fact, only winged insects pollinate the flower. Hive-bees, which are the most useful to the plant, enter the drooping bells without difficulty. When the object of a hive-bee's search is the pollen, "it thrusts its head, fore-legs, and mid-legs into the flower, clinging by means of its hind-legs to the outer surface of an inner perianth-segment. With the tarsal brushes of its fore- and mid-legs it sweeps pollen from the anthers and places it in the baskets on its hind-legs. If it wishes to suck honey, it usually finds it more convenient to use its own fore- and mid-legs for clinging to the perianth." * In either case the bee's head gets well covered with pollen, some of which is sure to be deposited on the stigma of the next flower which it visits, for the style of the Snowdrop projects beyond the anthers, and the bee's head must come in contact with the stigmatic surface on entering.

The *curvature* of many perianth leaves also subserves the purpose of excluding wingless insects from the nectar and pollen. "I placed," says Kerner, "some small and by no means timid ants, of a kind (*Lasius nigra*) which under ordinary circumstances show themselves to be capital climbers, on the flowers of *Cyclamen europæum* (fig. 441). At first they tried to make their escape downwards by the peduncle; but as I had put the flower-stalk in water, they turned back and managed to recross the calyx and get back to the corolla. After some useless clambering about the reflexed tips of the petals, they at last reached their curved

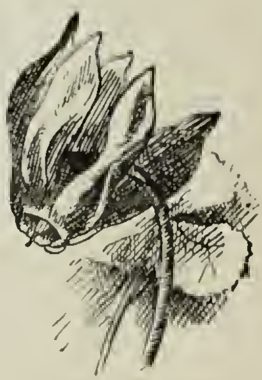
Fig. 441.—European Cyclamen.

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* *Fertilisation of Flowers.*

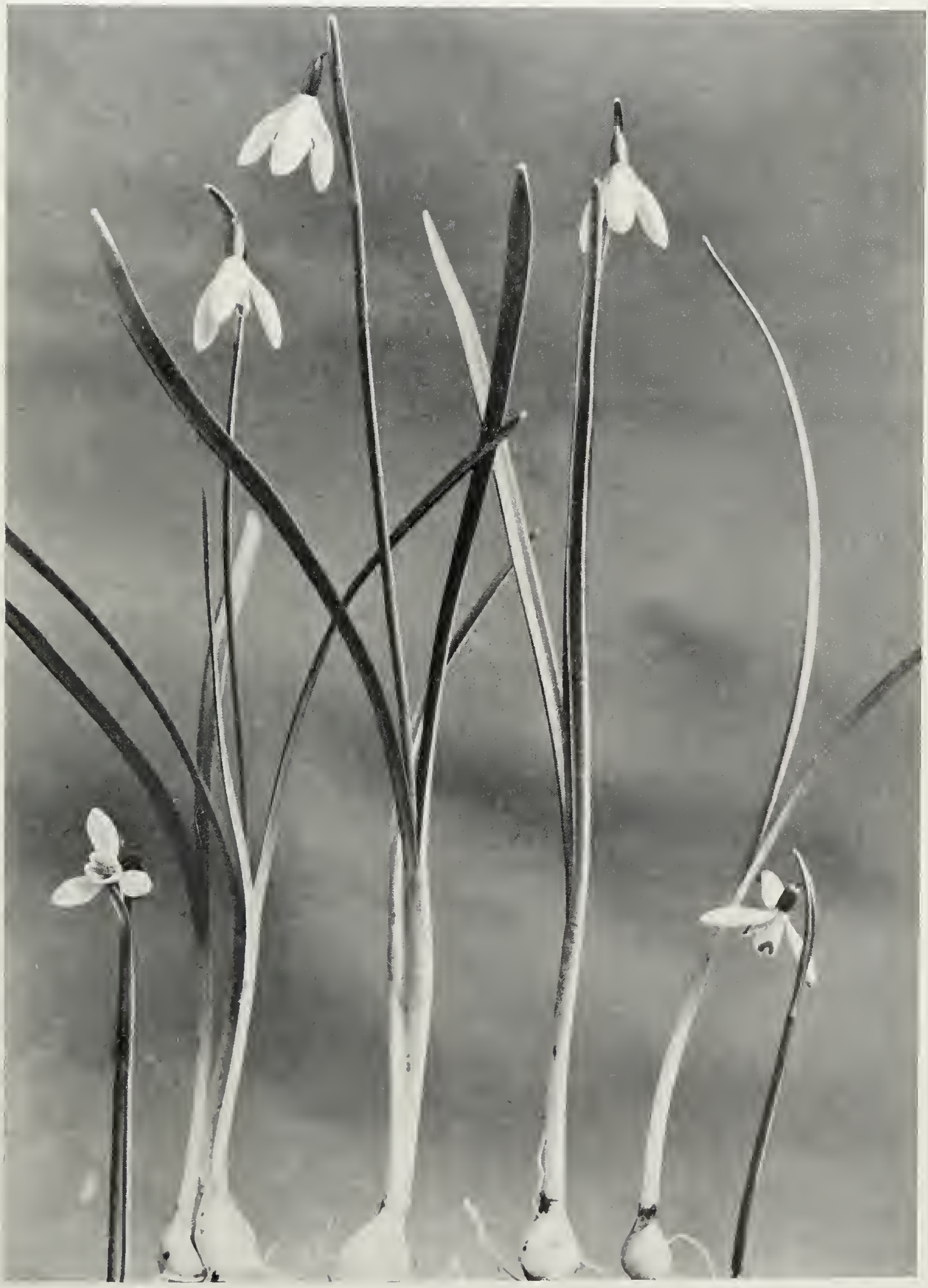


Photo by Henry Irving.

SNOWDROP (*Galanthus nivalis*) WITH PENDULOUS FLOWERS.

The Snowdrop produces but a single flower throughout the year, but this flower persists fresh and open for a long period; and hence, if deprived of the visits of hive-bees (its chief pollinators) for many days at a time (which may often happen in consequence of unfavourable climatic conditions), the ability to hold out is of great advantage to the plant.

PLATE XX.

margins, and here all their skill was baffled, and they fell either into the water or to the ground."

The calyx, epi-calyx, and bracts may be further protections to the flower, by preventing insects from eating their way through the corolla to the nectary, a burglarious proceeding of which even bees are sometimes guilty. We have seen how admirably an inflated calyx effects the same results, holding the would-be intruder at a distance from the honey, even when the tissue has been gnawed through; and the fact might be enforced by other examples. Hermann Müller remarks of one of the Louseworts (*Pedicularis verticillata*) that "the calyx is swollen, and the lower part of the corolla-tube is bent at right angles within the calyx; the honey is thus guarded from *Bombus mastrucatus*, which tries in vain to reach it." In the Canterbury Bell (*Campanula Medium*) the tough inflated hairy calyx, with its valvate divisions (fig. 442), stands above the ovary, the nectar being sufficiently guarded by the expanded bases of the five stamens which surround it (fig. 426); while in *Clarkia* (fig. 443) the curious boat-shaped gamosepalous calyx, like the curved petals of the Cyclamen referred to by Kerner, is an admirable contrivance for keeping out small wingless insects.

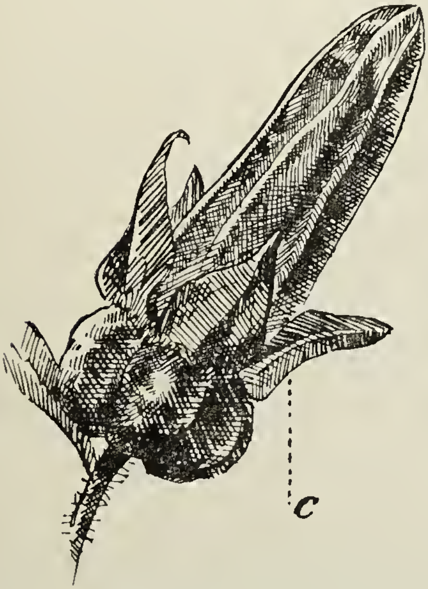


Fig. 442.—Flower-bud of Canterbury Bell. (c) Epigynous calyx.

We have seen how perfectly the flowers of *Antirrhinum* and Toadflax are adapted for the exclusion of certain intruders, and many equally perfect adaptations of corolla and calyx might be enumerated, where the same end is to be gained. In a number of instances, the corolla "forms a narrow tube, still further protected by the presence of hairs, sometimes scattered, sometimes, as in the White Dead-nettle, forming a row. In others the tube itself is so narrow that even an ant could not force its way down; while in some of the Gentians the opening of the tube is protected by the swollen head of the pistil. . . . In Clover (*Trifolium*), Birds-foot Trefoil (*Lotus*), and many other *Leguminosæ*, the ovary and the stamens, which cling round the

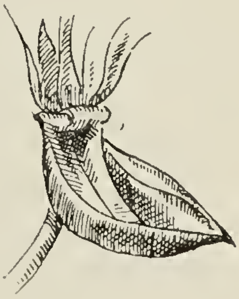


Fig. 443. — Curious gamosepalous calyx of *Clarkia*.

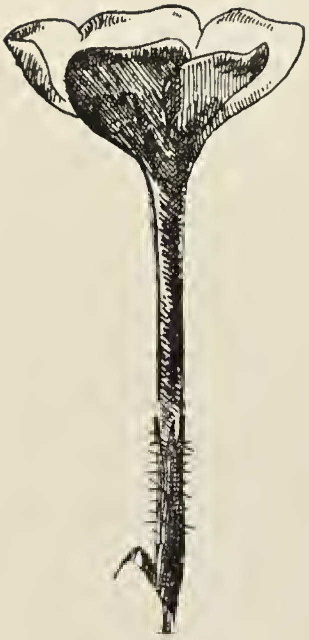


Fig. 444.—Flower of *Plumbago.*

ovary in a closely fitting tube, fill up almost the whole space between the petals, leaving only a very narrow tube. In still more numerous species the access of ants and other creeping insects is prevented by the presence of spines or hairs, which constitute a veritable *cheval de frise.* Often these hairs are placed on the flowers themselves, as in some Verbenas and Gentians. Occasionally the whole plant is more or less hairy; and it will be observed that the hairs of plants have a great tendency to point downwards, which, of course, constitutes them a more efficacious barrier" (Lord Avebury).

Lastly, in not a few cases creeping insects are kept away from the interior of the flower by viscid secretions on the stem or calyx, to which the unfortunate visitors get glued, and from which there is usually no escape. Thus the calyx of *Plumbago* (fig. 444) is furnished with glandular hairs, which stand out horizontally from the epidermis, and are fatal to many a wandering aphis and small fly. Here (fig. 445) is a sketch portrait of one of these luckless prisoners, together with four of the glandular hairs and a small portion of the tissue of the epidermis. The insect resembles in form, though it is much smaller than, those tiny green aphides of which ladybirds are so fond, and which are said to take the place of milk-cows in the ant world. The Honeysuckle (*Lonicera*) is another familiar instance of a flower which produces these viscid

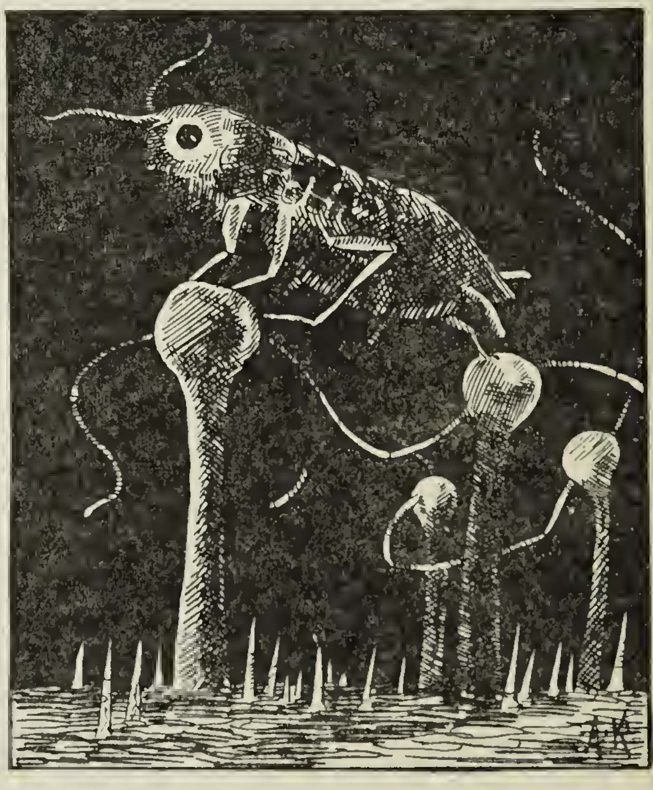


Fig. 445.—Glandular hairs of the calyx of *Plumbago capensis* with insect prisoner (much magnified).

protective hairs on its calyx (fig. 446), but in the Catchflies (*Silene nutans* and *S. noctiflora*) they are much more effective, as may be judged by the number of small insects usually found glued to the calyx and flower-stalk.

The Tutsan-leaved Dogsbane (*Apocynum androsemifolium*) is a plant which resorts to extreme measures in dealing with uninvited guests. The French call it *Gobe-mouche*, or Fly-gulper, and the name is well bestowed. In fact, the stamens of the flower have an ugly trick of nipping intruding flies by their probosces and detaining them as captives till death puts an end to their miseries. Then the filaments open and the dead insects are released. "Allured by the honey on the nectary of the expanded blossom," says Knapp, in his *Journal of a Naturalist*, "the instant the trunk [of the fly] is protruded to feed on it, the filaments close, and, catching the fly by the extremity of its proboscis, detain the poor victim writhing in protracted struggles till released by death, a death apparently occasioned by exhaustion alone; the filaments then relax, and the body falls to the ground. The plant will at times be dusky from the numbers of imprisoned wretches."

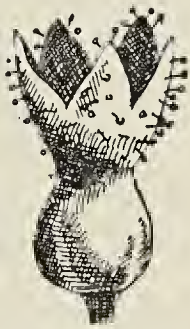


Fig. 446.—Glandular hairs on calyx of Honeysuckle.

More than one plant is known in which the expulsion of unremunerative visitors is effected, not by the plant itself, but by other and remunerative insects. Kerner has enumerated four of such plants—*Centaurea alpina*, *C. ruthenica*, *Jurinea mollis*, and *Serratula lycopifolia*, all of them belonging to the great Composite order. "The young capitula of these Composites," says the eminent naturalist, "are particularly liable to the attacks of devouring beetles, especially of *Oxythyrea funesta*, which bites big holes in the heads, destroying crowded flower-buds and involucral scales without the least difficulty. To meet this danger a garrison of warlike ants is employed. Honey is secreted from big stomata on the imbricating scales of the still-closed capitula in such quantities that one can see a drop of it on every scale in the early morning, while later in the day, as the water evaporates, little masses or even crystals of sugar are to be found. This sugar, either in its liquid or solid form, is very palatable to the ants, which habitually resort to these capitula during the period of its secretion, and to preserve it for themselves they resent any invasion from outside. If one of the afore-mentioned beetles appears, they assume a menacing attitude. They hold on to the involucral scales with their last pair of legs and present their forelegs, abdomen, and powerful jaws to the enemy. Thus they remain till the beetle withdraws, if necessary hastening its retreat by squirting formic acid in its direction."

It has been remarked that wingless insects are most active when the dew has evaporated, and that this is the signal for the closing of many flowers; but it may be doubted whether these circumstances stand in the relation of cause and effect. Flowers open and close at almost all times of the day and night; and though in some cases the periods of their opening have *distinct* reference to the visits of bidden guests, it seems extremely doubtful that the periods of their closing have any reference to unbidden ones. Be that as it may, the phenomena of the opening and closing of flowers are full of interest, and as the subject has been named, we will offer a few remarks upon it before passing on.

It is well known that Linnæus devised a *floral clock* at Upsala, by grouping together plants according to the hours at which they open and close, and that for a time the growing of these flower-clocks in public and private gardens became quite a rage. In recent years Kerner has repeated the experiment at Innsbruck (47° N. lat.), and a comparison of his tables with those of the older naturalist has shown that flowers both open and close earlier in the day at Upsala than at the more southerly situated Innsbruck. "The result," he says, "especially the earlier opening, is probably connected with the fact that the sun during the flowering season of the plants in question rises about an hour and a half earlier at Upsala than at Innsbruck."

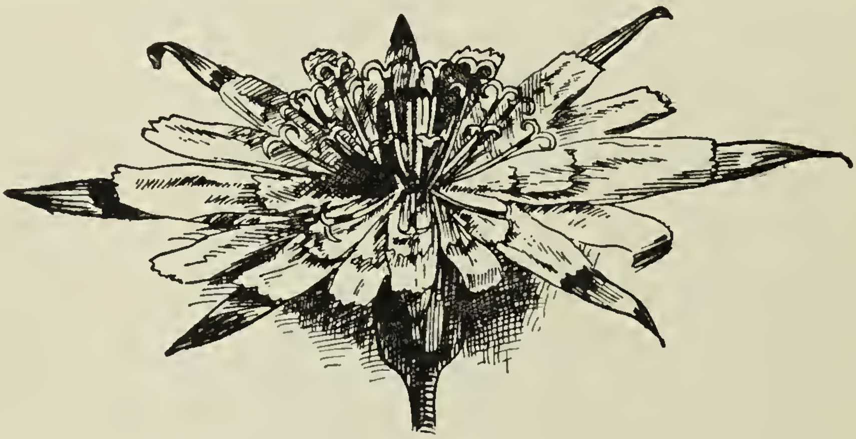


Fig. 447.—Flower of Yellow Goatsbeard.

Of the flowers in Linnæus's clock the earliest to open was the Yellow Goatsbeard (*Tragopogon pratensis*, fig. 447), a Composite flower like a large Dandelion, which has received in this country the name of John-go-to-bed-at-noon, from its habit of closing about mid-day.

> Broad o'er its imbricated cup
>   The Goatsbeard spreads its saffron rays,
> But shuts its cautious florets up,
>   Retiring from the noontide blaze.

The latest flower to open was the magnificent Queen of the Night, which unfolded its scentless white petals two hours before midnight.

Jean Paul Richter, referring to the Swedish naturalist's *horologium floræ*, compares it to the clock of human nature, in a passage which we cannot forbear quoting. "I believe," he says, "the flower-clock of Linnæus in Upsala, whose wheels are the sun and earth, and whose index-fingers are flowers, of which one always awakens and opens later than another, was what secretly suggested my conception of the human clock. I formerly occupied two chambers in Scheeraw, in the middle of the market-place; from the front room I overlooked the whole market-place and the royal buildings, and from the back one the botanical garden. Whoever now dwells in these two rooms possesses an excellent harmony, arranged to his hand, between the flower-clock in the garden and the human clock in the market-place. At three o'clock in the morning, the Yellow Goatsbeard opens, and brides awake, and the stable-boy begins to rattle and feed the horses beneath the lodge. At four o'clock, the little Hawkweed and the bakers awake, and choristers, who are clocks with chimes, wend their way to the cathedral. At five, kitchen-maids, dairy-maids, and Buttercups awake. At six, the Sowthistle and cocks; at seven o'clock, many of the ladies'-maids are awake in the palace, the Chicory in my botanical garden, and some tradesmen. At eight o'clock, all the colleges awake, and the little yellow Mouse-ear. At nine o'clock the female nobility already begin to stir; the Marigold; and even many young ladies, who have come from the country on visits, begin to look out of their windows. Between ten and eleven o'clock the Court ladies and the whole staff of lords of the bedchamber, the green Colewort and the Alpine Dandelion, and the princess's reader, rouse themselves out of their morning sleep, and the whole palace, as the morning sun gleams so brightly to-day from the lofty sky through the coloured silk curtains, curtails a little of its slumber. At twelve o'clock the prince, at one his wife and the Carnations have their eyes open. What awakes late in the afternoon (at four) is only the red Hawkweed and the night-watchman as cuckoo-clock; and these two tell the time as evening-clocks and moon-clocks. From the hot eyes of the unfortunate man who, like the Jalap-plant (*Mirabilis Jalapa*), first opens them at five o'clock, we will turn our own in pity aside. It is a rich man who has taken the jalap, and who only exchanges the fever-fancies of being gripped with hot pincers for waking gripes. I could never know when it was two o'clock, because at that time, together with a thousand other stout gentlemen, and with the yellow Mouse-ear, I always fell asleep; but at three o'clock in the afternoon, and at three in the morning, I woke as regularly as though I was a repeater. Thus we mortals may be flower-clocks for higher beings, when our flower-leaves close upon our last bed; or sand-clocks, when the sand of our life is so run down that it is renewed in the other world; or picture-clocks, because, when our death-bell here below strikes and rings, our image steps forth from its case into the next world. On each event of the kind, when seventy years of human life have passed away, they may perhaps say, 'What! another hour gone! How the time flies!'"

We approach now a new and more important division of the subject—namely, the means by which the pollen of flowers is conveyed to the stigma as a preliminary to fertilisation. The consideration of these means brings us of necessity in touch with those denizens of the insect world which may be reckoned among the *bidden* guests of flowers. The subject has received an extraordinary amount of attention during the last few years, and is practically inexhaustible. The phenomena of which it treats are themselves often spoken of as fertilisation, but this use of the term—albeit we confess to being frequent offenders in this respect—is hardly correct. Pollination is a better word.

Let us begin with flowers which pollinate themselves. Now it will be evident at a glance that such flowers must bear the male and female organs on the same individual; hence we call them *bisexual* or *hermaphrodite.* Hermaphroditos, in Greek mythology, was the son of Hermes (Mercury) and Aphroditē (Venus), and became united into one body with a nymph of Mount Ida while bathing in the fountain of Salmacis.

The presence or absence of one or both of the essential organs of a flower is a matter of great importance. One of the commonest hermaphrodite flowers is the Buttercup (*Ranunculus*, fig. 306). Here the male and female organs are both present in the shining yellow cup, and hence it is not only bisexual, but *perfect.* Even though the Buttercup had no calyx or corolla, it would still be perfect. As a matter of fact it possesses both those organs; and since, in addition, it possesses both pistil and andrœcium, it is said to be *complete.* The absence of *any* of the four organs—calyx, corolla, andrœcium, or pistil—renders a flower *incomplete*; but only the absence of one of its *essential* organs (*i.e.*, the andrœcium or the pistil) renders it *imperfect.* We are speaking, of course, not of that which is accidental and abnormal, but of that which is characteristic of the flower. Thus the Common Ash (*Fraxinus excelsior*),

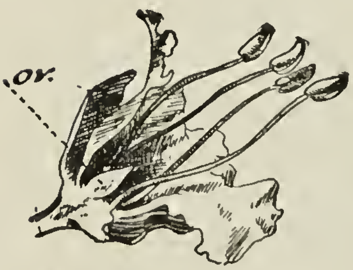


Fig. 448. — Section of male flower of Horse-chestnut, showing stamens and rudimentary ovule (*ov*).

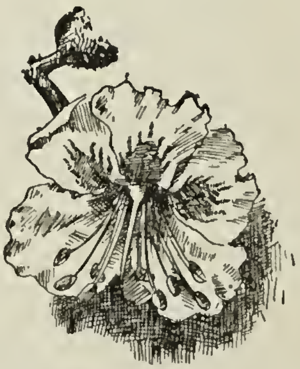


Fig. 449.—Hermaphrodite or bisexual flower of same

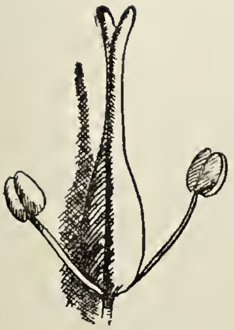


Fig. 450.—Flower of Common Ash.

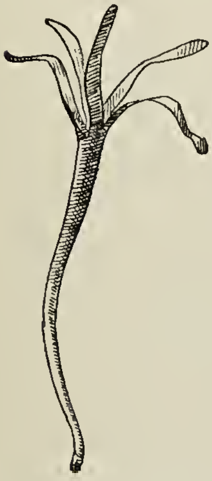


Fig. 451.—Neuter flower from the circumference of a Star Thistle (*Centaurea*).

which bears its male and female organs on the same flower (fig. 450), but has no floral envelopes whatever, is a perfect flower; while, on the other hand, the Arrowhead (*Sagittaria*), in the different species of which both calyx and corolla are always present, but which bears the sexes on different flowers, is imperfect. We need hardly add that, in both cases, the flowers are incomplete. It is, then, evident that all imperfect flowers are either male or female; if the former, they are called *staminate*; if the latter, *pistillate*—names which explain themselves; while flowers which have neither male nor female organs are described as *neuter*. Of this latter kind are the outer florets of some of the Composites (fig. 451).

Now, though the sexes are often separated in the manner described, staminate and pistillate flowers are not always or necessarily borne on different plants. We might, indeed, liken the andrœcium and pistil to tenants in a house where the rooms are flowers and the house itself is the plant. When, as in the Oak (*Quercus Robur*), Walnut (*Juglans regia*), and Sweet Chestnut (*Castanea sativa*), the male and female flowers occupy the same house, they are said to be *monœcious* (Greek *monos*, one, and *oikos*, house); when, as in the Juniper (*Juniperus*), Poplar (*Populus*), and Willow (*Salix*, fig. 452), the sexes not only occupy different rooms, but different houses, being borne on distinct plants, the flowers are appropriately termed *diœcious* (Greek *di*, two, and *oikos*). Hence, too, the plants themselves are capable of sexual classification, some being male, others female, others bisexual, and a fourth class, in which male, female, and hermaphrodite flowers are found on one and the same individual, *polygamous*.

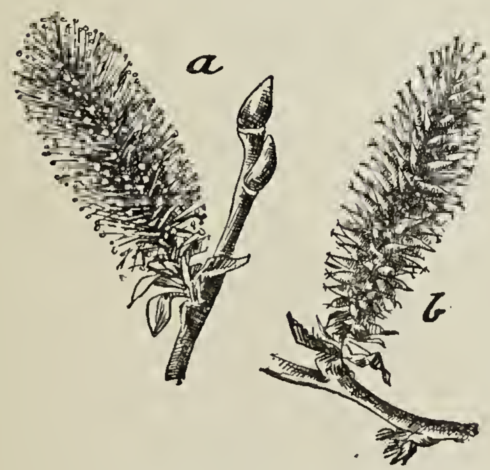


Fig. 452.—Male (*a*) and female (*b*) catkins of Goat-willow (*Salix caprœa*).

With this digression, let us revert to the subject which led to it—the pollinating of a flower by its own anthers. The process of self-pollination is the first stage of autogamy, which, as already explained, is the fecundation of a flower by its own pollen; and the whole process may, and sometimes does, take place without the flower opening at all. It has, indeed, been discovered by comparison of several closely allied flowers that the smaller ones are frequently self-pollinated—nay, that in some cases the *same* plants which produce ordinary cross-pollinated flowers produce minute self-pollinated ones which never open. Thus we may say that there are two kinds of autogamous flowers—those which open like ordinary flowers, and those which remain closed. A glance at an example or two will make the fact additionally clear.

To take the last-named first. These, as the whole process is effected in the closed flowers, are called *cleistogamic*, a name derived from the Greek *kleistos*, closed, and *gamos*, marriage. The Henbit Dead-nettle (*Lamium amplexicaule*) offers excellent examples of cleistogamic flowers. The richly tinted reddish-purple corollas of the expanded blossoms of this not uncommon weed are familiar to most persons (fig. 453, *a*). They are met with in dry and sandy fields during the sultry months of July and August; but few probably have noticed, earlier in the year, the small bud-like unexpanded flowers of this plant (fig. 453, *b*). These are cleistogamic flowers, which *never* open—undeveloped flower-buds, with anthers and stigmas that mature so that perfect fruits are produced. Were you to open one of these buds at the moment of pollination (453, *c*), you would find that the long and flexible style (*st*) had curled round so as to bring the inner side of its forked stigma in contact with one of the anthers. Perhaps you would even find that the anthers had not opened, but that the pollen-tubes had perforated its delicate walls and were growing in the direction of the stigma.

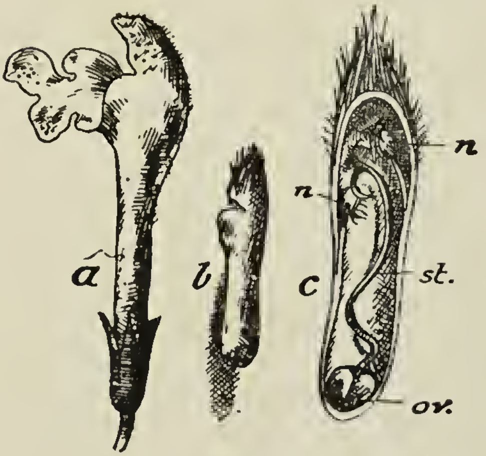


Fig. 453.—Cross-fertilised and cleistogamic flowers of Henbit Nettle. (*a*) A cross-fertilised flower. (*b*) A cleistogamic flower. (*c*) A cleistogamic flower in section: (*n n*) anthers; (*st*) style; (*ov*) ovary.

The Dog-violet (*Viola canina*) is another plant which produces these undeveloped flowers. Professor Ainsworth Davis remarks that "in summer the ripe fruit of the cross-pollinated flowers will be found, and, close to them, minute bud-like structures. These are the cleistogamic flowers; their anthers are so placed that the pollen-grains can send their tubes straight to the stigma. Such a flower produces, perhaps, only two hundred pollen-grains, as opposed to some thousands in an ordinary blossom." As a rule, indeed, cleistogamic flowers are pollen saving. Thus, a single self-pollinating flower

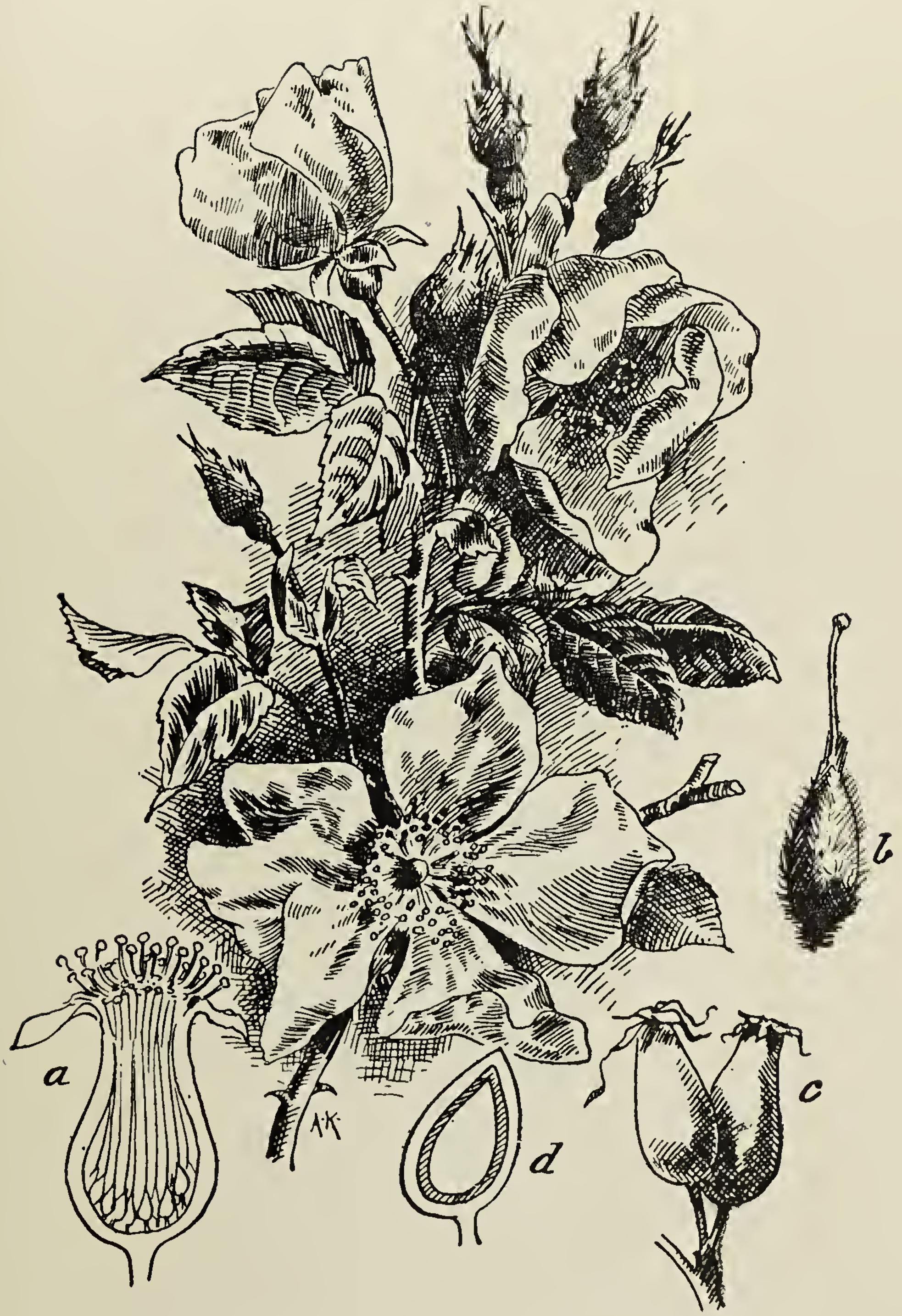


Fig. 454.—Dog-rose. (*a*) Flower cut lengthwise after fall of petals and stamens. (*b*) A single fruit. (*c*) The hip, in which the fruits are enclosed. (*d*) Section through a ripe seed.

of Wood-sorrel (*Oxalis*) contains about four hundred grains; a flower of Touch-me-not Balsam (*Impatiens Noli-me-tangere*) about two hundred and fifty; and of Cut-grass (*Leersia*) not above fifty. Contrast these figures with the number of pollen-grains in the Peony, 3,500,000, or in a single flower-head of Dandelion, 365,000!

There is a species of Bitter-cress (*Cardamine chenopodifolia*) which has cleistogamic flowers that burrow into the earth. They spring from underground runners or stalks, and are produced earlier than the open flowers, which are borne upon aerial shoots. Charles Darwin and others have asserted the same thing of the cleistogamically produced capsules (seed-vessels) of the Violet; but Professor Henslow, in his *Origin of Floral Structures*, appears to doubt the correctness of the observation. He explains that they certainly are "very, if not more, frequently, not buried at all, but only concealed beneath the foliage."

In the cleistogamic flowers of the Common Wood-sorrel (*Oxalis Acetosella*) the unopened corolla forms a sort of cap, which may be removed entire, although, in the flowers that open, the petals do not cohere at all. We have noticed a similar curious fact in the flowers of the Common Dog-rose (*Rosa canina*, fig. 454). The blossoming time of the plant is June and July, but sometimes it produces buds as late as September, and these buds may remain closed and pollinate themselves, though whether the fruit in such case ever matures is doubtful.

The production of cleistogamic flowers appears to depend upon various causes, the chief of which are the *time of blossoming* and the *influence of climate*. Of these causes the latter is the most important. In Southern Italy, for example, the climate can develop normally expanding flowers, and render them fertile, so that cleistogamy is suppressed; whilst here in England the climate is seemingly not sufficiently warm to do this, and cleistogamic buds appear as compensation. The vegetative energy comes to the fore during the summer, but expanding flowers are not produced simultaneously with it; indeed, as Henslow observes, "it is not until the vegetative period has ceased, and the materials are remade for their development, that larger flowers are again borne"—that is to say, "later in the year, as in November, and also in the following spring."

We come now to the second class of autogamous flowers—namely, those which develop in the normal way, and expand (or, at least, are capable of expansion) at the period of maturity. This class, as has already been explained, comprises all self-pollinating flowers which are not cleistogamic. It must not be supposed, however, that self-pollinating flowers are never cross-pollinated. As a matter of fact, the former process is often only adopted as a last resource. The various species of *Myosotis* offer interesting illustrations of this truth. Thus the Wood Scorpion-grass (*M. sylvatica*) is usually cross-pollinated by flies; but if no insects appear, the anthers shed their pollen directly upon the stigma, which lies conveniently below it (fig. 455, *a*). The Yellow and Blue Scorpion-grass (*M. versicolor*) protrudes its stigma from the flower when ready for pollination (fig. 455, *b*); but if the usual agents in this process—bees and flies—do not appear, the corolla-tube elongates, and by that means its sessile anthers, which form a circle on the interior surface of the tube, are rubbed against the knotted stigma (fig. 455, *c*). In the Forget-me-not (*M. palustris*) anthers and stigma are on a level, so that self-pollination is sure to take place in the absence of insects (fig. 455, *d*).

Take the Common Groundsel (*Senecio vulgaris*), again. It is one of the Composites, and each of its capitula bears from sixty to eighty inconspicuous tubular florets, which vary in length from one-tenth to one-eighth of an inch. Marginal or rayed florets, which might serve to attract insects, it has none, and hence, though the honey is easily accessible, the plant seldom gets visited. In this case, therefore, self-pollination takes place almost as a matter of necessity. The styles are furnished at their tips with tiny brushes, which sweep out the pollen-grains in a most effectual manner, holding them fast to the edges of the stigmas, into which the delicate tubes soon push their way.

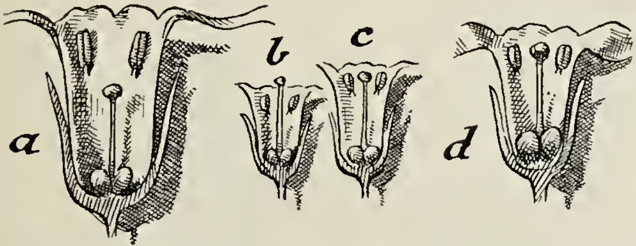


Fig. 455.—Sections of flowers of different species of *Myosotis*. (*a*) Wood Scorpion-grass. (*b c*) Yellow and Blue Scorpion-grass. (*d*) Forget-me-not.

Perhaps such diminutive flowers as those of *Myosotis* and Groundsel are not the best examples that might be chosen to illustrate the facts before us, and it will be helpful to name a familiar flower of larger growth, which, though normally cross-fertilised, occasionally pollinates itself. Such a flower is the well-known Garden Convolvulus (*Ipomœa purpurea*, fig. 456). "Whilst the flowers are young," says Darwin, "the stigma projects beyond the anthers (fig. 456), and it might have been thought that it could not have been fertilised without the aid of humble-bees, which often visit the flowers; but as the flower grows older the stamens increase in length, and their anthers brush against the stigma, which thus receives some pollen." Its action, indeed, resembles that of *Myosotis versicolor*, save that the bringing of the anthers to a level with the stigma is effected by the lengthening of the stamens—not of the corolla-tube. Kerner asserts that the process of autogamy in *Ipomœa* is further facilitated by the involution of the corolla, which occurs at the close of flowering, whereby the anthers coated with pollen are pressed against the stigma.

Self-pollination by means of the style, which we have described as taking place in the Groundsel, may be seen to more advantage in the larger florets of most species of the Knapweed family (*Centaurea*), as well as in most of the Willow-herbs (*Epilobium*, fig. 457). Take, for instance, the beautiful Blue Mountain Centaury (*C. montana*, fig. 458). This plant has a very long list of insect visitors, and yet, when need so requires, the florets are quite competent to pollinate themselves. The drawings (fig. 458, *b*, *c*, and *d*) will explain how the various organs go to work. At *b* we have a floret from the centre of the capitulum, and at *c* and *d* representations of the style-branches on a greatly enlarged scale; at *h* is a circle of hairs. The anthers are united into a tube which conceals the greater part of the style and is itself almost concealed by the corolla-tube. The anthers open towards the style, upon which in consequence they shed their pollen (introrse dehiscence), and, as might be expected, a good deal of the precious dust gets scattered on the hairs. Here, unless removed by insect agency, it remains until the florets enter upon their last stage; when the style-branches roll back, and in so doing bring their stigmatic surface in contact with the pollen on the circlet of hairs. Thus autogamy is effected (fig. 458, *d*).

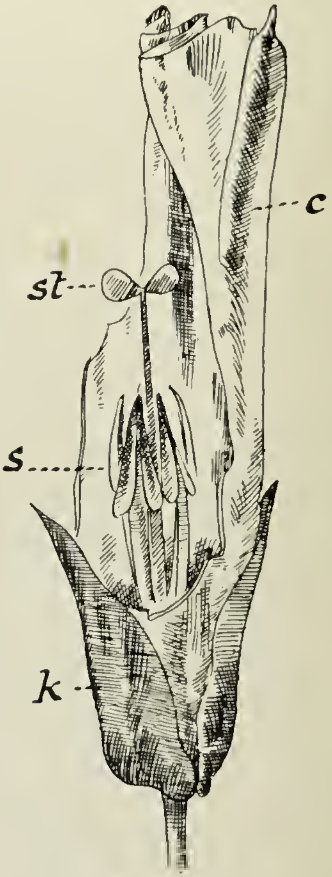


Fig. 456.—A portion of the flower of *Ipomœa purpurea*. (*c*) Torn part of the corona. (*k*) Calyx. (*s*) Stamens. (*st*) Stigma.

To describe even a tithe of the means by which the same important end is brought about in other flowers would require more space than the scope of this work allows. In the case of pendent flowers like the Snowdrop (*Galanthus*) and *Soldanella*, where the style projects beyond the stamens, the pollen may get sprinkled on the stigma; and this may also be the case in upright flowers when the anthers are placed above the stigmatic surface, as in the Lilac (*Syringa*). We have seen how the lengthening of stamens may bring about autogamy, and instances are not uncommon in which the curving or erecting of those organs fulfils the same purpose. The pistil, too, may shorten or elongate, curve or straighten, when self-pollination is the object; or (as in the case of the Mountain Centaury above described) the stigma itself may be adapted to this end. The important part which the petals sometimes play in this process was clearly indicated in what was said concerning the elongation of the corolla-tube in *Myosotis versicolor*; nor is this the only means by which autogamy is effected by the corolla. In gamopetalous flowers, like the Foxglove (*Digitalis*), the end may be gained by the loosening and falling of the corolla, the adherent stamens brushing against the stigma as the corolla slips along the style, while in flowers with free petals the very closing of the corolla may ensure self-pollination. An excellent illustration of this last method is afforded by the Devil's Fig (*Argemone mexicana*, fig. 459), whose handsome yellow flowers bloom only for a single day. Kerner remarks that "in the morning, as soon as the petals are wide open and the tension of the sheath of stamens surrounding the pistil is somewhat relaxed, there is an immediate fall of pollen on the concave surfaces of the petals. . . . When the evening comes the petals close up over the pistil, and one of them brings its inner surface, which is covered with pollen, into direct contact with the stigma." *Apropos* of this subject, it has been observed of the Water-crowfoot (*Ranunculus aquatilis*) that when the stream in which it is found is much swollen after rain, the flowers remain submerged and fertilise themselves without opening.

In the beautiful Climbing Cobæa (*Cobœa scandens*) we

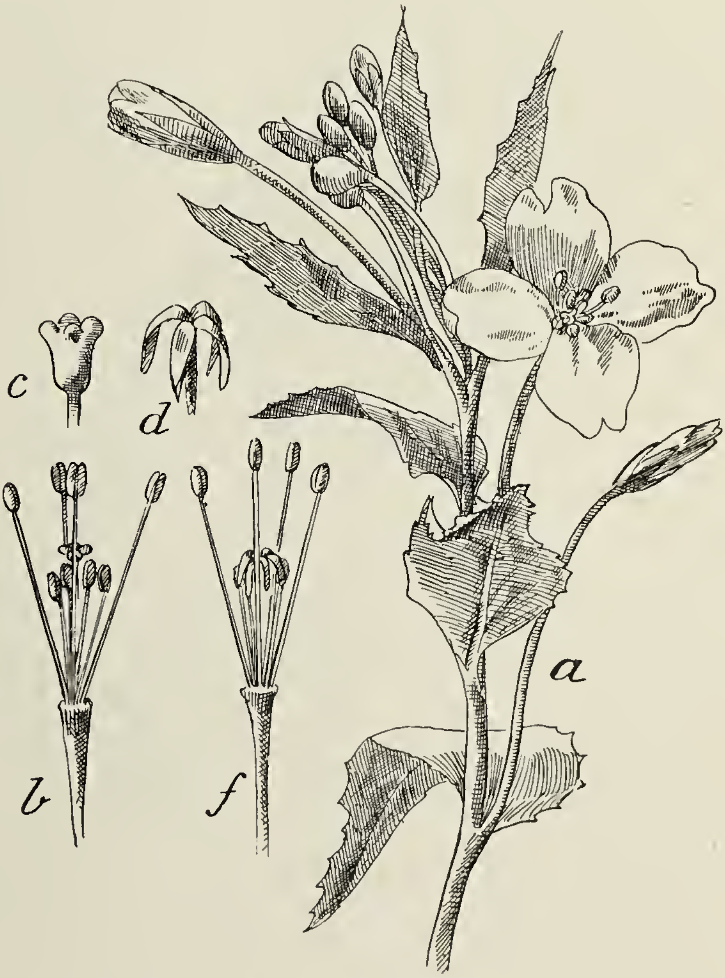


Fig. 457.—A species of Willow-herb. (*a*) Flowering branch. (*b c*) Stamens and pistil laying themselves out for cross-fertilisation. (*d f*) The same in the condition for self-fertilisation: the stigma has curled backwards and come in contact with the shorter stamens.

see how autogamy may be effected by a co-operation of movements. On the expansion of the bud, insect-pollination is the first object provided for, and while the campanulate corolla nods invitingly on its stem, the anthers, which are borne on long filaments with hairy bases, lie right in the mouth of the bell, just where the first humble-bee visitor will be sure to knock against them (fig. 460). During this stage the style remains out of sight, with its three-forked stigma tightly closed. In the second stage, anthers and stigma change places, and the filaments of the former, lengthening considerably, twist themselves up like corkscrews. This is the insect's last chance, and now, should no fertilisation have taken place, the flower enters upon its third and final stage. For this, it assumes a completely pendent position (fig. 461). While anthers and stigma draw together, the branches of the latter open and present their stigmatic surfaces, and, finally, the pollen falls upon them. On

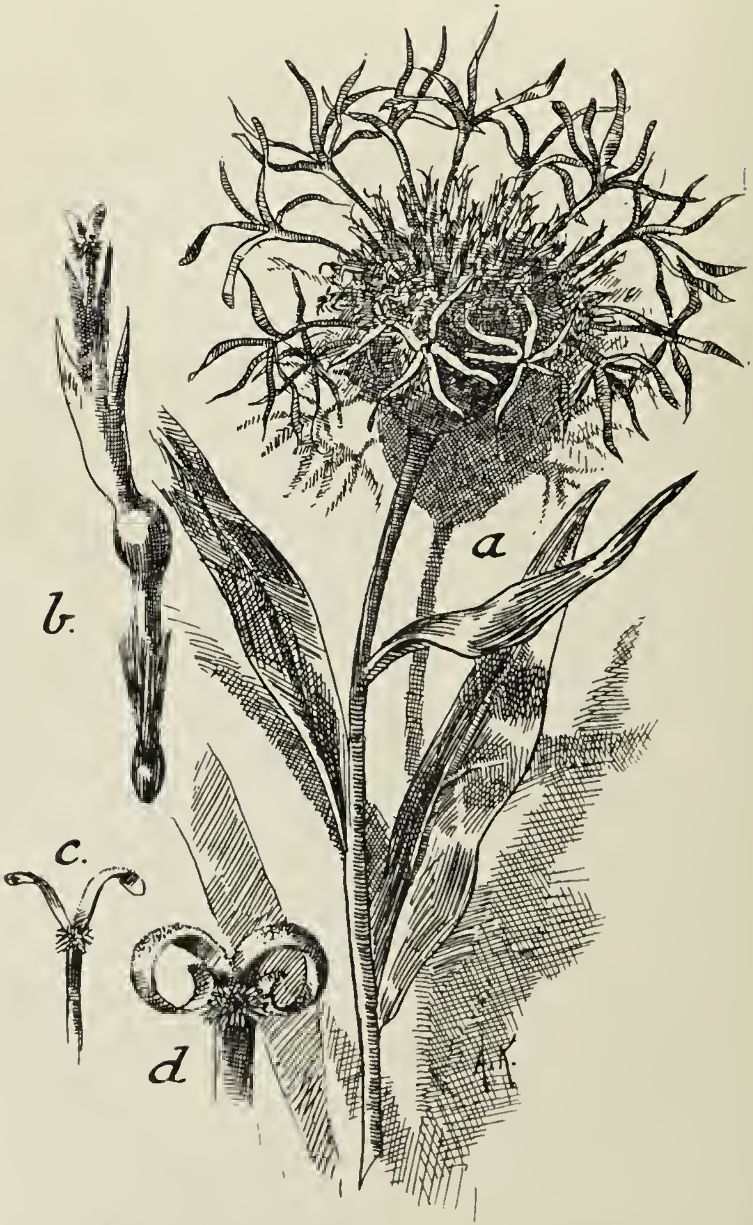


Fig. 458.—*Centaurea montana.* (*a*) The inflorescence. (*b*) Floret from the centre of capitulum. (*c*) Style-branches of same with collecting hairs. (*d*) The same rolled back so as to bring the stigmatic surface in contact with the pollen on the collecting hairs.

the whole, it is a wonderful instance of the parts of a flower co-operating to a given end.

From what has been said it will be abundantly clear that though the pollen of a bisexual flower may effect the pollination of that flower, such a result is by no means inevitable; indeed, as a matter of fact, a very large number of bisexual flowers are almost always cross-pollinated; and Darwin has shown pretty conclusively that in many plants cross-fertilisation has a distinct advantage over self-fertilisation—*at least, for some generations*—inasmuch as the flowers thus crossed produce more numerous seeds and healthier seedlings.

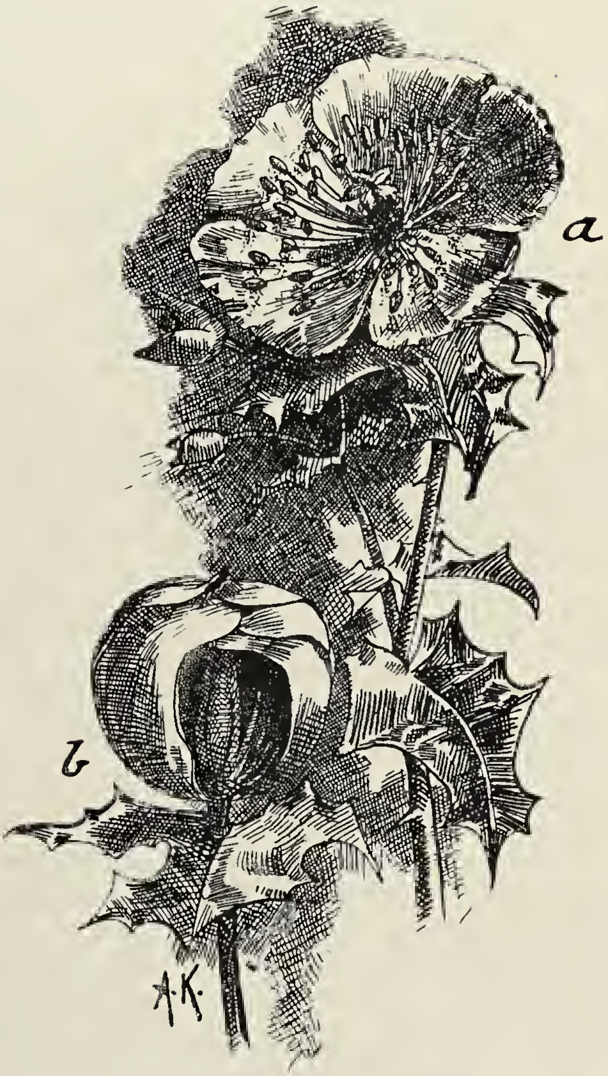


Fig. 459.—*Argemone mexicana.* (*a*) Open flower anthers dropping pollen into the concave petals. (*b*) Closed flower (front petal removed). One of the pollen-besmeared petals now lies upon the stigma.

This is not the place to discuss the much-debated question whether, *in the long run*, plants are gainers by cross-fertilisation. It is a point upon which botanists are still divided. One eminent observer, Professor George Henslow, says emphatically that *habitually* self-fertilised plants are the most prolific, and that our previous ideas, based upon Darwin's experiments and theories, are all wrong, and must be reversed. "The most conspicuous flowers and regularly (if at all) fertilised by insects are not," he asserts in his *Making of Flowers*, "the best off; *but they cannot help themselves.* The responsive power within them is *automatic*, so to say, and not *volitional.* Whatever an insect does to them, they must yield to it, and grow in adaptation to it, but while they are thus being stimulated to become what *we* may choose to call finer flowers and handsomer plants with larger leaves and so on, yet all

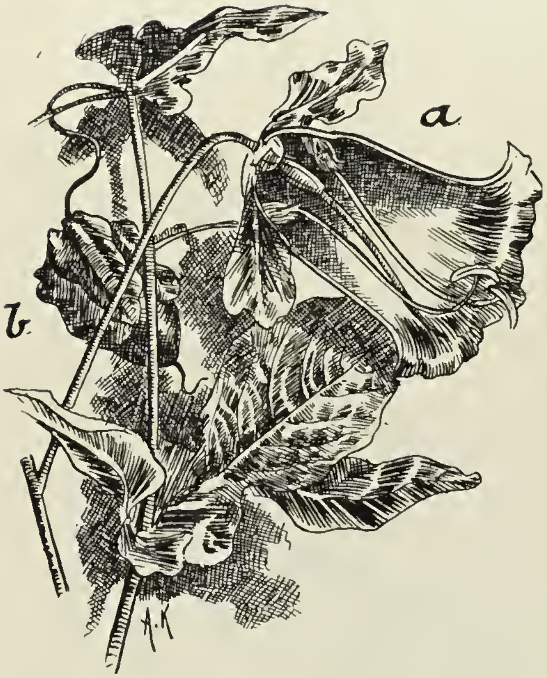


Fig. 460.—Climbing Cobæa. (*a*) Section of flower in first stage of development. (*b*) Fruit of another flower.

this is secured at a sacrifice of fertility." He contends that though Darwin proved that intercrossing is a *stimulating process*—at least, for a time—his experiments also went to show that "when the two processes were continued for a few years the plants derived by successive self-fertilisation in a few generations not only recover themselves, so to say, but sooner or later surpassed in fertility the descendants of plants successfully intercrossed for the same number of years."

However, the fact remains. Cross-fertilisation occurs much more frequently in Nature than self-fertilisation; and this truth may be readily accepted without committing oneself to the startling dictum of Darwin that Nature abhors self-fertilisation.

A *via media* between Darwin and Henslow is offered in Edward Step's *Romance of Wild-flowers*: "The small but ubiquitous Shepherd's Purse (*Capsella Bursa-Pastoris*) may be taken as a type of the inconspicuous-flowered weeds of this family [*Cruciferæ*], which fertilise themselves, and produce such abundance of seed that they take possession of all cultivated ground so soon as the husbandman's back is turned. Their flowers range in diameter from one-fourth to one-twelfth of an inch, and in some cases the petals have been converted into stamens as being more useful to plants once dependent upon the visits of insects, but which have now learned to do without them. The presence of these minute white petals, and in some cases honey-glands that no longer secrete honey, testifies to the fact that these plants have come down in the world. Yet, in spite of their lack of show or 'presence,' they are a standing rebuke to those writers who have so strongly asserted that cross-fertilisation produces a more vigorous and successful race. What cross-fertilisation by insect agency does is to produce more brilliant individuals, and to keep up large flowers of bright hue. In fact, it produces a kind of floral aristocracy; whilst the principal work of the vegetable kingdom—the abstraction of carbon from the atmosphere, the setting free of

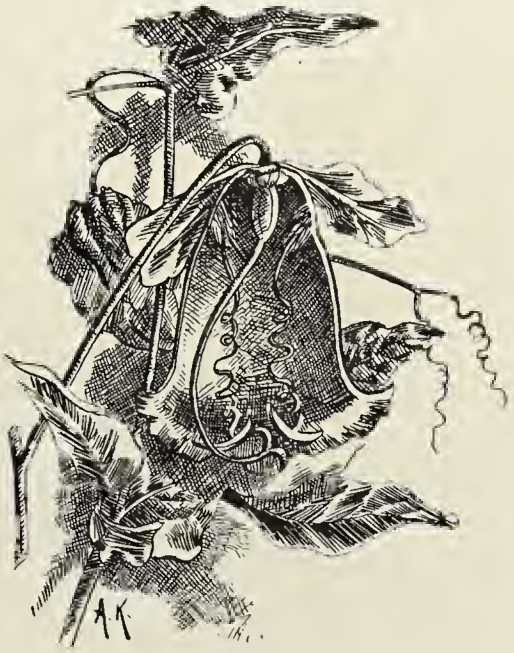


Fig. 461.—The same, showing a flower in second stage of development.

oxygen, the production of food for the entire animal races—is done mainly by the less brilliant weeds and grasses and trees—the working classes."

We have seen how certain bisexual flowers adapt themselves to self-pollination; we may next consider how another class of flowers, also bisexual, provide against it. This brings us to the phenomena of dichogamy, upon which we must say a few words. The term is derived from the Greek *dicha*, in two parts, and *gamos*, marriage; and whenever the reproductive organs (stamens and pistil) of a bisexual flower mature at different times we have an instance of dichogamy, and the flower is said to be a dichogamous flower. When the stamens mature first, so that the pollen in their anther-lobes escapes before the stigma in the same flower is ready for pollination, the flower is said to be *proterandrous* (Greek *proteros*, before, and *andros*, male); and this is the case in most species of *Geranium*, *Pelargonium*, *Malva*, *Umbelliferæ*, *Compositæ*, and *Campanulaceæ*. When, on the other hand, the stigma matures and loses its capacity for pollination before the anthers of the same flower have shed their pollen, the flower is said to be *proterogynous* (Greek *proteros*, before, and *gunē*, a female). Some species of *Magnolia*, *Aristolochia*, *Scrophularia*, and *Plantago* have proterogynous flowers, but they are much less common than are the other kind.

The Blue Meadow Cranesbill (*Geranium pratense*, fig. 462)—the largest of our British Cranesbills—is a good example of a proterandrous flower. It might at first sight be thought to be a self-pollinating flower, for at the time when the anthers dehisce they are bent right over the pistil; but at this stage in the flowering the pistil is immature, and the stigmatic tissue is protected from pollen falling upon it. At a later period, however, when the anthers have diverged away from the pistil, the latter matures, its fine branches expand, exposing the stigmatic surface, and the flower is cross-pollinated by insect agency.

The Common Birthwort (*Aristolochia Clematitis*, figs. 463, 464) is a remarkable instance of a proterogynous flower. Fig. 464 shows a section through the swollen base of the dull yellow perianth, in

Fig.—462.—Blue Meadow Cranesbill.

the interior of which we see the six-lobed stigma and a few of the anther-lobes, which are sessile on the short style. Now the stigma of this Birthwort matures two or three days before the anthers are ripe, and at the time of its maturity the flower is entered by small black midges of the genera *Ceratopogon* and *Chironomus*. It will be noticed that the dull yellow corolla of the flower is swollen at the base, but contracts above into a tube which is lined, in the first stage of the flower, with stiff downward-pointing hairs. Along this tube the midges crawl in quest of refreshment, which they find in the succulent tissue that forms the smooth walls of the roomier chamber below. From the centre of the floor of this chamber uprise the six short stamens, the anther-lobes of which are adnate to the stigmatic column. Their meal finished, the midges rest awhile, soothed by the warmth of the apartment. Then they turn to depart. But egress is a different thing from ingress, and on crawling to the tube they find that escape is cut off. The hairs which they had passed over so easily are now a stockade of bristling points. The little guests are prisoners!

What is to be done? At first the midges take the calamity with philosophic calmness, and explore their prison with evident care. In the course of their explorations they crawl and recrawl over the stigmatic surface, and—supposing them to have come from another flower—fertilise the ripe stigma with the pollen which they have brought thither. Hours pass away: the stigma withers; but the midges are still held captive. A whole day goes by—two days—and release seems as far off as ever. They become anxious and restless. On the third day the anthers open and discharge their pollen, and the midges, worked up by this time into a fine bustle of alarm, get repowdered with the yellow meal. Their term of imprisonment is now at an end, for lo! the prison bars have collapsed—the stockade of hairs has completely withered, and the midges pass easily out of the flower, laden with an abundant freight!

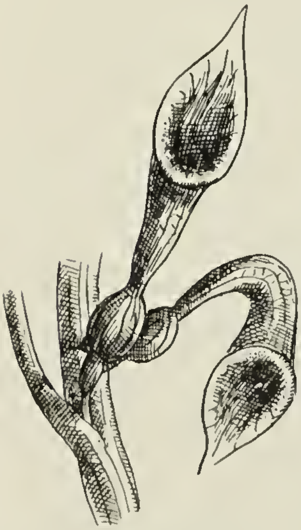


Fig. 463.—Flower of Common Birthwort.

In the well-known window-plant, *Aspidistra* *elatior*, the flowers are sometimes proterandrous and sometimes proterogynous, and self-fertilisation is still further guarded against by the curious mushroom-like stigma, which covers the anthers umbrella-fashion, so that the stigmatic surface is quite out of reach of pollen from the same flower (fig. 465). "The capitate stigma closes the flower, leaving only four small openings through which Delpino supposes small flies to enter; the pollen falls out of the anthers and lies in the cavity of the flower. The flies emerge all dusted with pollen, and alighting on the stigma of another flower place pollen there before they find the small entrance" (Müller). These remarks apply equally to the other species of Aspidistra—*A. lurida*, *punctata*, etc. The flowers referred to are also visited by numbers of *Poduridæ*, probably for the sake of the pollen, some of which they may carry from flower to flower.

An even more curious way in which bisexual flowers lay themselves out for cross-fertilisation without irregularity is known as *heterostylism.* The law is well illustrated in many plants of the Primula family, to which the Primrose, Cowslip, and Oxlip (fig. 466) belong. "Most children are aware," says Grant Allen, "that we have in our woods two kinds of Primroses, which they know respectively as pin-eyed and thrum-eyed. In the pin-eyed form, only the little round stigma is visible at the top of the pipe, while the stamens, here joined with the corolla-tube, hang out like little bags half-way down the neck of it. In the thrum-eyed form, on the other hand, only the stamens are visible at the top of the tube, while the stigma, erected on a much shorter style, occupies just the same place in the tube that the stamens occupied in the sister blossom. Now each Primrose-plant bears only one form of flower. Therefore, if a bee begins visiting a thrum-eyed form, he will collect pollen on his proboscis at the very base only; and as long as he goes on visiting thrum-eyed

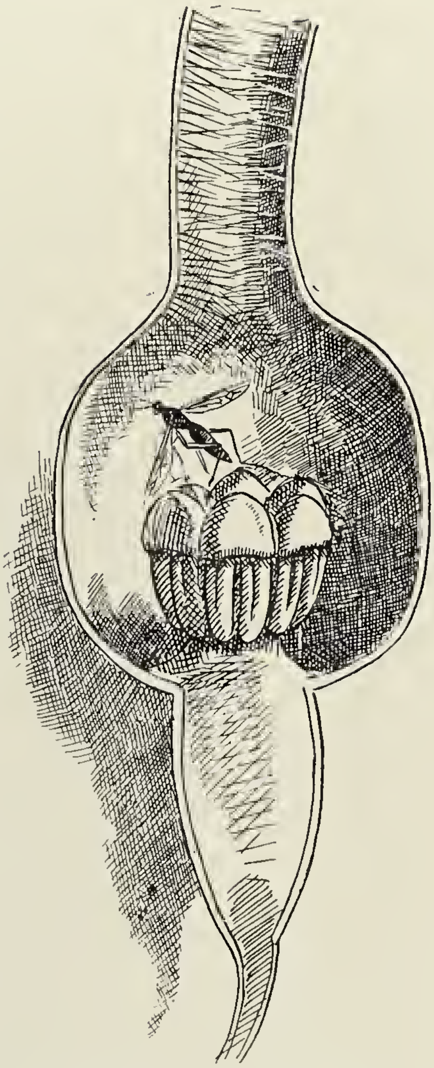


Fig. 464.—Section through lower portion of flower of same, to show palisade of hairs, stamens, pistils, etc.

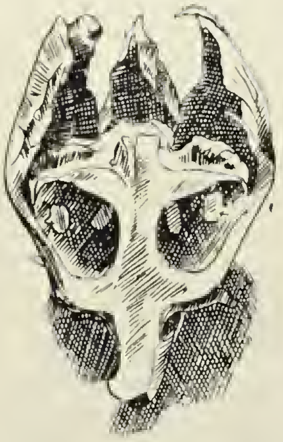


Fig. 465.—Section through a flower of *Aspidistra*, showing sessile stamens and curious mushroom-like stigma.

flowers, he can only collect, without getting rid of any grains on the deep-set stigmas. But when he flies away to a pin-eyed blossom, the part of his proboscis which collected pollen before will now be opposite the stigma, and will fertilise it; while at the same time he will be gathering fresh pollen below, to be rubbed off on the sensitive surface of a short-styled flower in due season. Thus every pin-eyed blossom must always be fertilised by a thrum-eyed, and every thrum-eyed by a pin-eyed neighbour."

Heterostylism is carried to an extreme in *trimorphic* flowers, where, besides a long- and a short-styled form, we get a third condition, to which Darwin has applied the name "mid-styled." The flowers of Purple Loosestrife (*Lythrum Salicaria*, figs. 467, 468) offer, perhaps, the best examples of trimorphism. The three forms are shown with diagrammatic stiffness in fig. 467, the floral envelopes (calyx and corolla) having previously been stripped off. Comparing the different forms: in the left-hand figure (*a*) there are six short stamens, six mid-length stamens, and a long style; in the central figure (*b*) there are six short stamens, six long ones, and a mid-length style; and in the right-hand figure (*c*), six mid-length stamens, six long ones, and a short style. Now the singular fact about these flowers is this: the long-styled forms are almost invariably fertilised by pollen from long stamens; the mid-styled forms by pollen from mid-length stamens; and the short-styled forms by pollen from short stamens; and hence, of course, the flowers are usually cross-pollinated. Darwin, indeed, has shown that when fertilisation takes place under other conditions — when, for instance, a long-styled flower is pollinated by short or mid-length stamens—the seeds produced are smaller and less healthy.

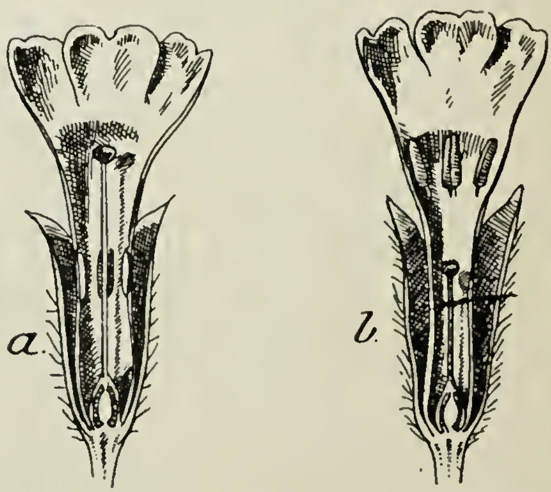


Fig. 466.—(*a*) Pin-eyed and (*b*) thrum-eyed flowers of Oxlip (*Primula elatior*).

Hermann Müller tells us that when the flower of Purple Loosestrife is fully expanded—which, however, owing to the crowded nature of the spike, is not often—"the upper petals stand vertically while the lower project obliquely forward; and the latter form, therefore, a rudimentary platform for insects. The irregularity in position of the stamens and pistil is of more importance; they all occupy the inferior (outer) part of the tube, so that insects cannot reach the base of the flower between them, but only above them; and their ends are bent upwards, so that the ventral surface of the insect must come in contact both with anthers and stigma. Honey is secreted by the fleshy base of the flower, and surrounds the short stalk of the ovary, and fills the space between it and the sides of the tube. Insects are attracted from a distance by the crimson spikes of flowers, and are guided on their way to the honey by the dark red colour of the inner surface of the calyx and by the dark lines in the middle of each petal. These insects are caused to perform regular cross-fertilisation by the trimorphism of the flowers, which forms the most remarkable feature of the plant."

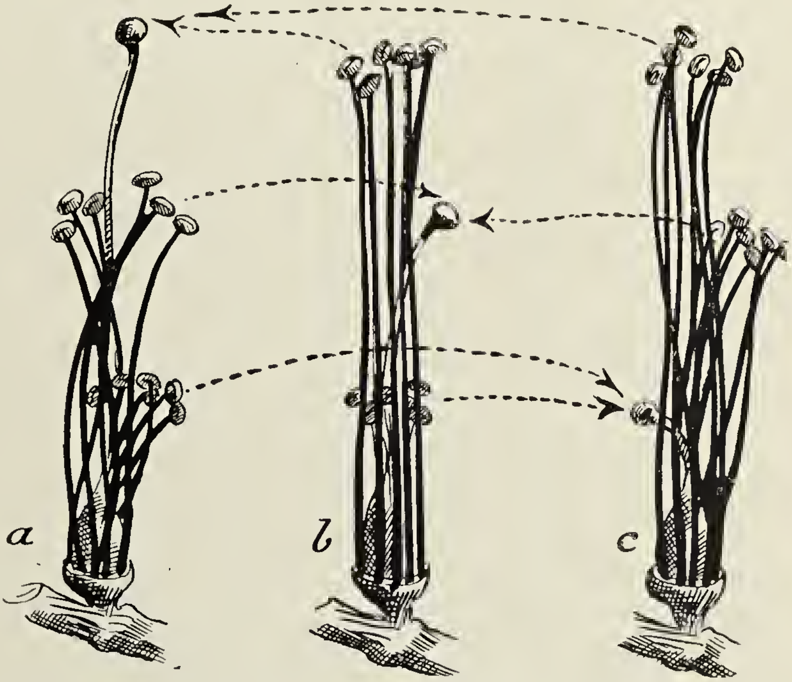


Fig. 467.—Trimorphism in Purple Loosestrife. (The calyx and corolla have been removed.)

The arrangements in Nature for securing the cross-fertilisation of plants are by no means exhausted with the phenomena of dichogamy and heterostyly. These provisions are doubtless the rule among insect-pollinated flowers, but there are innumerable exceptions to the rule; and, moreover, all cross-fertilised plants do not owe their pollination to insect agency. Other animals, such as snails and birds, sometimes perform this office; and in a large number of cases wind and water are the pollen-carriers. For the present, however, we may confine ourselves to flowers that are pollinated by insects.

We have already shown that many flowers are specially adapted, either by their form or mechanism, for the visit of certain insects; and further, that the colours, scents, and nectareous sweets of such flowers act as lures to the guests that are wanted. The flower, indeed, as a talented writer in *Harper's Magazine* remarks, "is no longer a simple passive victim in the busy bee's sweet pillage, but rather a conscious being, with hopes, aspirations, and companionships. The insect is its counterpart. Its fragrance is but the whisper of welcome, its colour is as the wooing blush and rosy lip, its portals are decked for his coming, and its sweet hospitalities humoured to his tarrying; and as it finally speeds its parting affinity rests content that its life's consummation has been fulfilled."

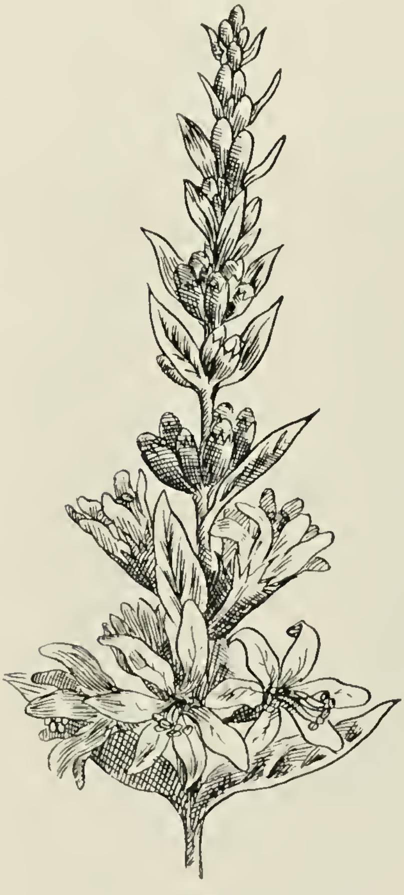


Fig. 468.—Inflorescence (spike) of Purple Loosestrife.

In considering the means by which insects are attracted to flowers, six important features may be specially noted. These are Conspicuousness, Odour, Irregularity, Honey-guides, Nectar, and Pollen. Let us take them in their order.

Size, colour, and the massing of flowers are the three chief causes of *Conspicuousness*. Of these the first and last need not be dwelt upon. It is obvious that the larger a flower is, the greater are its chances of attracting attention; equally obvious is it that small flowers which cluster together (say as umbels or flower-heads) have a decided advantage over flowers of the same size which are solitary. Then there is colour. The bright colours of flowers, and in some cases the bright tints of the adjoining parts, such as the flower-stalks, bracts, etc., have evident reference to the visits of insects; indeed, it was the opinion of Sprengel, a German botanist of the eighteenth century, that "flowers differ in colour in accordance with the kinds of insects which frequent them." That bees readily distinguish colour has been proved by Lord Avebury, and the experiments of Darwin point to the same conclusion. "It is a curious question," he writes, "how bees recognise the flowers of the same species. That the coloured corolla is the chief guide cannot be doubted. On a fine day, when hive-bees were incessantly visiting the little blue flowers of *Lobelia Erinus*, I cut off all the petals of some, and only the lower striped petals of others, and these flowers were not once again sucked by the bees, although one actually crawled over them. The removal of the two little upper petals alone made no difference in their visits. Mr. J. Anderson states than when he removed the corollas of the Calceolaria, bees never visited the flowers."

That this is not a rule without exception, however, Darwin has himself pointed out. He shows clearly enough that colour is not the only insect guide, and offers the common-sense suggestion that insects may be able "to recognise plants even from a distance by their general aspect, in the same manner as we should do." We may add that the entire removal of the corollas of several flowers of the Garden Convolvulus (*Ipomœa purpurea*)—an experiment which we tried in a Dulwich garden not long since—did not hinder bees from visiting those flowers; indeed, they seemed to resort to them more freely than to the unmutilated flowers, though the latter were fully expanded at the time.

Sprengel's opinion has been quoted that "flowers differ in colour in accordance with the kinds of insects which frequent them," and it would be easy to bring forward an array of arguments in support of this view. It has been noticed, for example, that the favourite colours of the honey-bee are blue, violet, crimson, purple, and deep violet-blue, particularly the last-named; but that scarlet, orange, and yellow attract them but little—if at all. Possibly, as Kerner suggests, the nerve-bundles which correspond to those colours are wanting in their eyes. Butterflies and humble-bees, on the other hand—particularly the large humble-bee, *Monarda didyma*—are very partial to scarlet. Scarlet appears also to be the favourite colour of humming-birds; and the fact is to be noted that scarlet flowers abound in those countries where humming-birds are found. Crepuscular and night-flying insects are most affected by white and yellow, a circumstance easily accounted for, since the deeper-coloured flowers become invisible when twilight falls.

Flies and beetles which frequent dung-heaps and offal are drawn to greenish yellow or brownish yellow flowers, like the Parsley and Ivy, the Aralia (fig. 469) and Sumach; and "this phenomenon has been explained by the similarity of the colours named with those of the dung-heap and offal generally" (Kerner). Wasps, which are so partial to decaying fruit, seem to have a predilection for dark brown; whilst carrion-flies are most susceptible to pale fawn-red and dirty violet, the prevailing tints in decaying flesh. Hermann Müller says of the gigantic *Amorphallus Titanum* (fig. 470), whose spathe is thirty-three inches in diameter, and the bare part of whose floral axis attains a length of

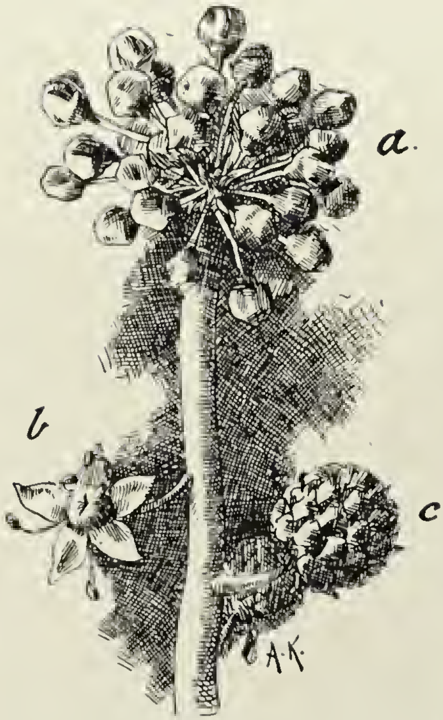


Fig. 469.—Flower buds of *Aralia nudicaulis*. (*a*) Umbel of unopened flowers. (*b*) Abnormal growth of a single flower. (*c*) Umbel at an earlier stage of growth.

six feet, that it "is adapted by its dirty yellow and dark purple colours for dung- and carrion-flies." A more familiar example is our own little Cuckoo-pint (*Arum maculatum*). All such flowers give out an offensive odour which serves as an additional attraction to carrion-loving flies.

Physiologically speaking, the cause of the colours of flowers (as, indeed, of fruits also) is the existence of pigments in their cells, either dissolved or in solid particles. The colouring principles are the same as in autumn leaves—namely, anthocyanin and phylloxanthin. Thus the yellow hue of the florets of the Dandelion is due to microscopic bodies of protoplasm tinged with a yellow pigment, which are contained in the epidermal cells; while the colour of the Pheasant's-eye (*Adonis autumnalis*) is due to a red pigment. In the last-named flower the particles are less than $\frac{1}{8000}$ of an inch in diameter. In blue, violet, and (so-called) black flowers (which are probably in most cases a deep shade of violet), the colouring matter is usually dissolved in the cell-sap. White flowers do not derive their whiteness from any pigment, but from the fact that their epidermal cells are filled with air. Professor Thomé has shown in the case of *Zinnia elegans* how peculiarly the separate pigments of a flower may be distributed in different superimposed layers of cells. "The marginal florets of the capitulum are scarlet on the upper and light yellow on the under side, while the layers of cells nearest the surface contain a purple sap with orange granules. The rest of the cells are filled with a colourless sap in which float a smaller number of light yellow granules."

The changes in the colours of flowers, like the changes in the colours of leaves, are due to oxidation. The Common Borage (*Borago officinalis*) changes from pink to blue; and the pale pink bells of the young flowers of the Garden Convolvulus (*Ipomœa purpurea*) frequently change to a deep purple as they mature. These are familiar instances of oxidation in cells containing the blue colouring principle (anthocyanin). Yellow flowers, on the other hand, if they change at all, keep to their own

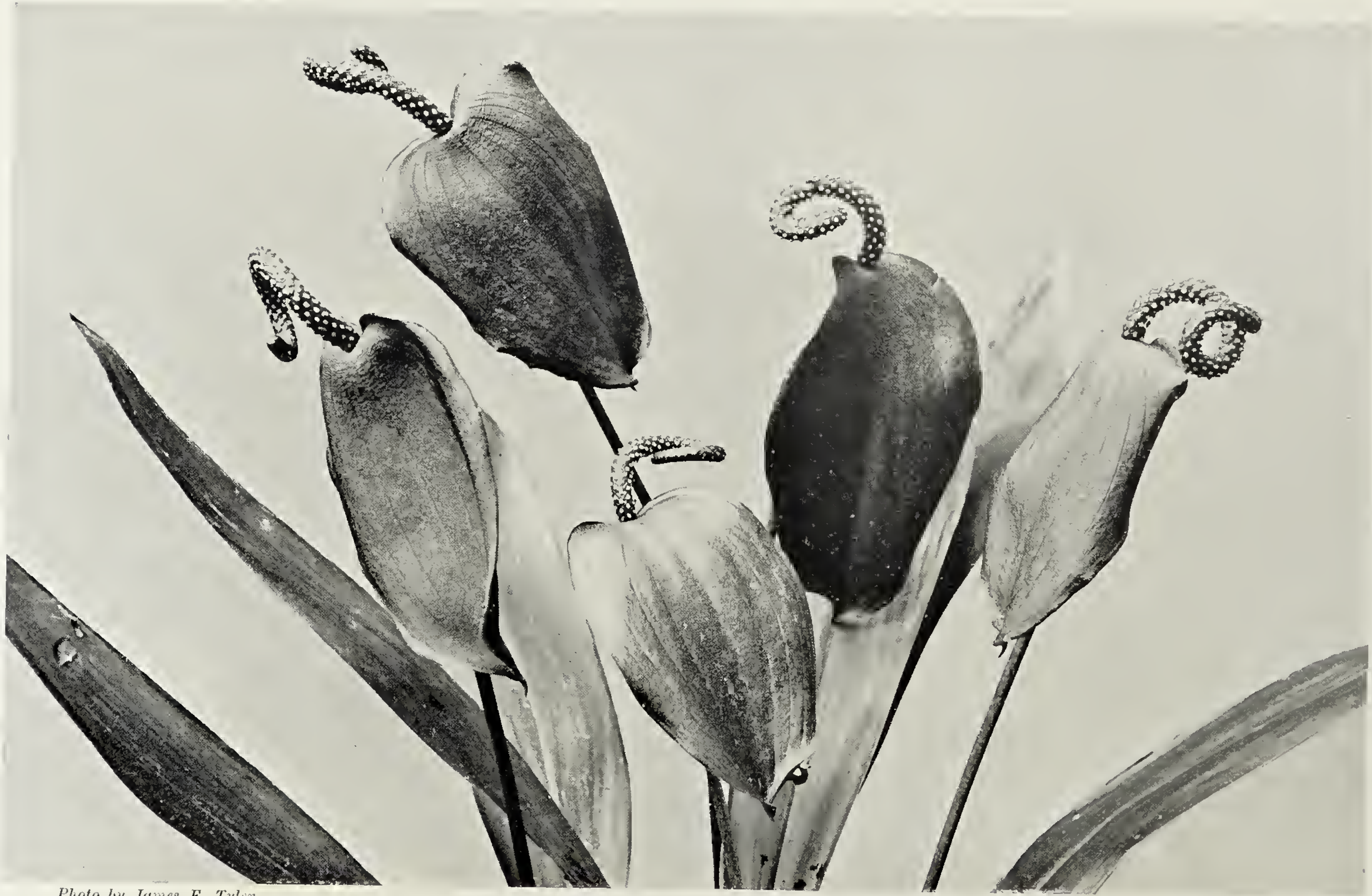


Photo by James E. Tyler.

FLAMINGO-PLANT (*Anthurium Scherzerianum*).

The spathes of this plant, which is a native of Central America, are of an intense and brilliant scarlet, but the flowers yield no honey, and are therefore avoided by humming-birds and butterflies. It is thought, however, that flies and beetles may be attracted to them.

PLATE XXIII.

series of colours—oranges and pure reds—so that there is fitness in De Candolle's division of flowers into *xanthic* and *cyanic*—a yellow series and a blue.

Here, as elsewhere in Nature, the rule is not without exceptions. Thus, the Yellow and Blue Scorpion-grass (*Myosotis versicolor*) changes from yellow in the bud to blue in the open corolla; and the Common Hyacinth (*Hyacinthus orientalis*), whose generic name denotes a deep purply blue colour, is not infrequently pale yellow. Other exceptions might be pointed out.

Kerner draws attention to a third colouring principle, a scarlet-red pigment, as yet little known; but notably present in the blood-coloured inflated calyx of the Winter Cherry (*Physalis Alkekengi*, fig 354). It may serve, he thinks, to frighten animals. If this be so, the brilliant hues of flowers must in some instances be looked upon as means of repulsion rather than of attraction.

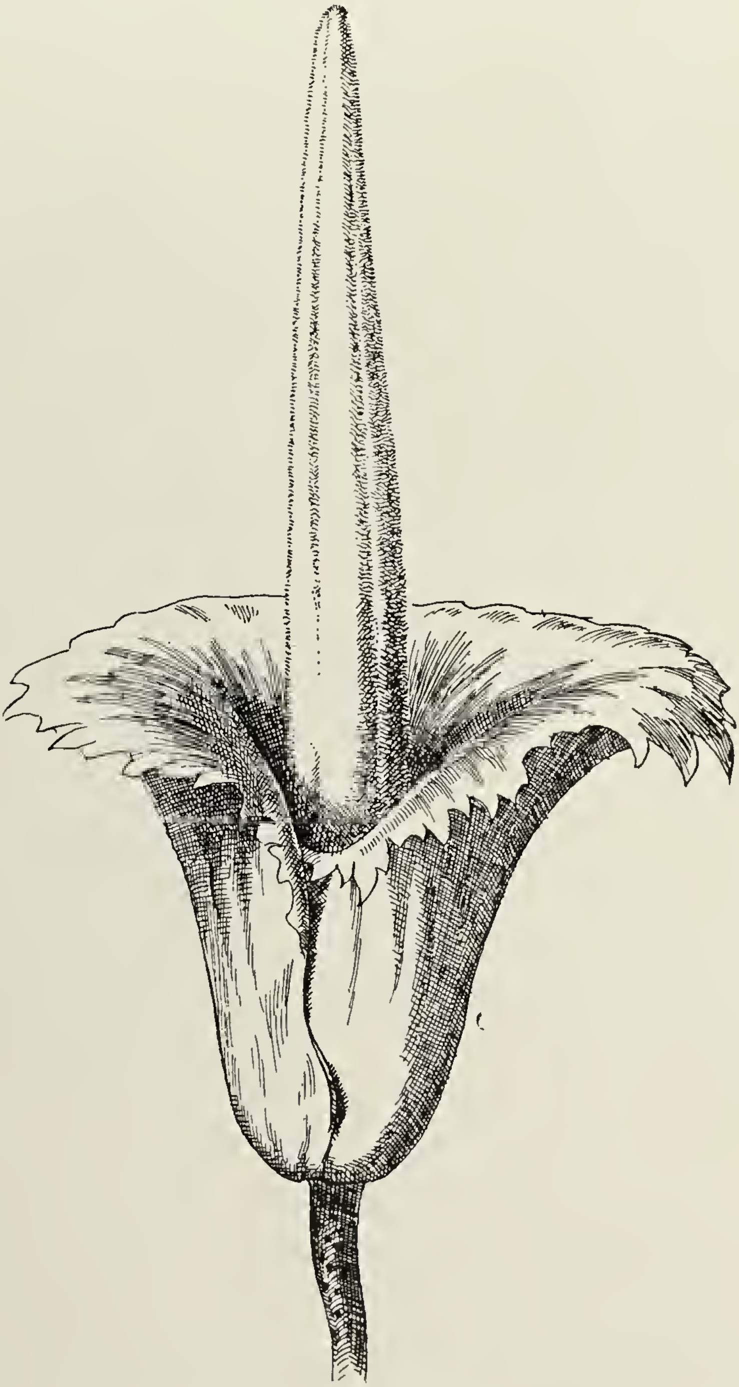


Fig. 470.—Giant Arum (*Amorphallus Titanum*).

From Conspicuousness we come to *Odour*. Odour and Conspicuousness are the two means by which insects are attracted to a plant *from a distance*, just as honey-guides facilitate their search for the nectary when the flower is reached. That odours really do attract insects has been attested by Darwin, who found that they visited flowers which he had covered with muslin nets. The same naturalist tells us that "Nägeli affixed artificial flowers to branches, scenting some with essential oils and leaving others unscented; and insects were attracted to the former in an unmistakable manner. . . . Of all flowers," he further remarks, "white is the prevailing one; and of white flowers a considerably larger proportion smell sweetly than of any other colour—namely, 14·6 per cent.; of red, only 8·2 per cent. are odoriferous. The fact of a larger proportion of white flowers smelling sweetly may depend in part on those which are fertilised by moths requiring the double aid of conspicuousness in the dark and of odour. So great is the economy of Nature, that most flowers which are fertilised by crepuscular or nocturnal insects emit their odour chiefly or exclusively in the evening. Some flowers, however, which are highly odoriferous, depend solely on this quality for their fertilisation, such as the night-flowering Stock (*Hesperis*) and some species of Daphne; and these present the rare example of flowers which are fertilised by insects being obscurely coloured."

Conspicuousness and Odour usually go together, but this is not always the case. The flowers of the Willow, Lime, and Mignonette are notable exceptions. The hypanthodium of the Fig (fig. 471) is another. What attracts the wasp to the Fig? Not the brightness of its densely packed unisexual flowers, for they are hidden quite out of sight. It is the odour. Were it not for the odour the flower might remain unvisited and would probably never get fertilised, for the Fig is proterogynous. In fact, the two kinds of Fig-tree—*Caprificus* and *Ficus*, as the Italians call them—stand to each other in the relation of male and female, being, broadly speaking, the different sexes of the one species, *Ficus carica*; and each appeals to the olfactory sense of insects with a distinct purpose. *Caprificus* may be popularly regarded as the "male tree"—*i.e.*, its hypanthodia produce male flowers near the opening (*ostiole*) and abortive female flowers, known as gall-flowers, lower down. *Ficus* is the "female tree"; its inflorescences, which form the edible fig, contain only female flowers.

Concerning these gall-flowers, some very remarkable facts are known. "As the name indicates," says Kerner, "not fruits but galls are produced from these modified female flowers, and this happens in the following manner. There is a small wasp . . . *Blastophaga grossorum*, which lives upon the Fig cultivated in the South of Europe (figs. 472-474). This insect passes into the cavity of the inflorescence through the orifice, and there sinks its ovipositor right down the style-canal of a flower and deposits an egg close to the nucellus of the ovule. The white larva developed from the egg increases rapidly in size and soon fills the entire ovary, whilst the ovule perishes. The ovary has now become a gall. When the wasps are mature they forsake the galls. The wingless males are the first to emerge, and they effect their escape through a hole which they bite in the gall.

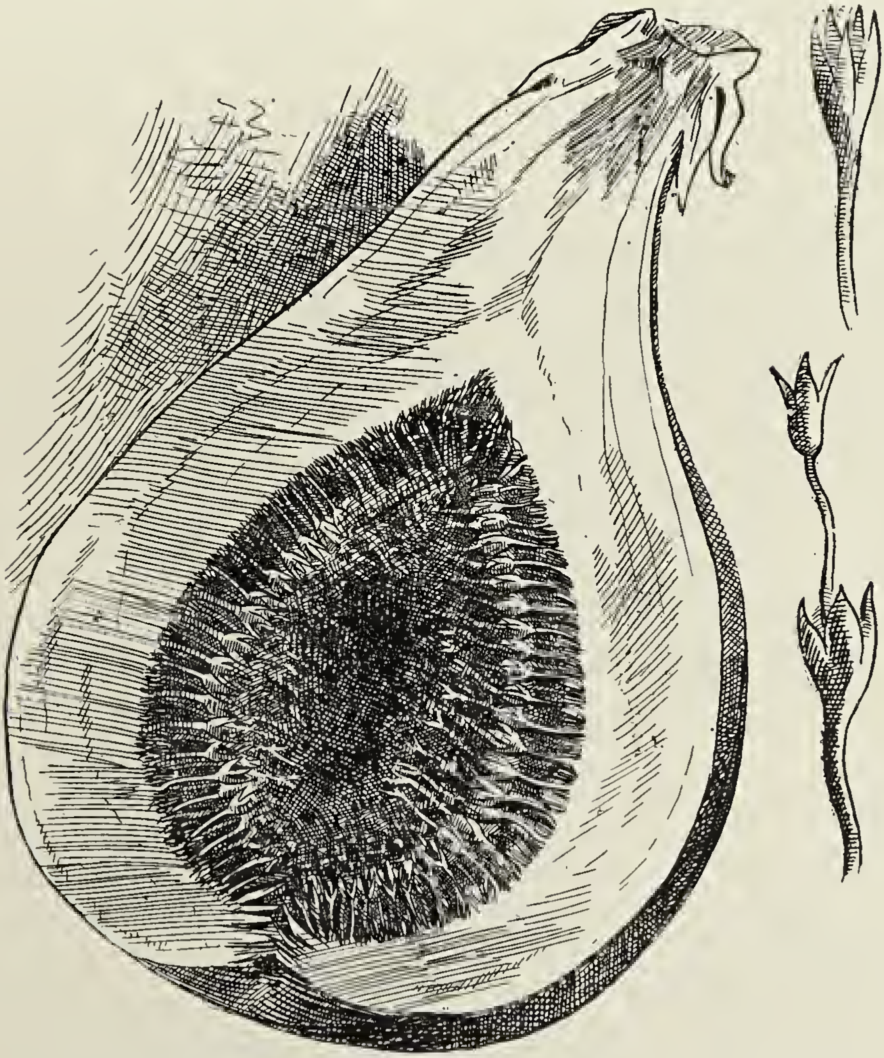
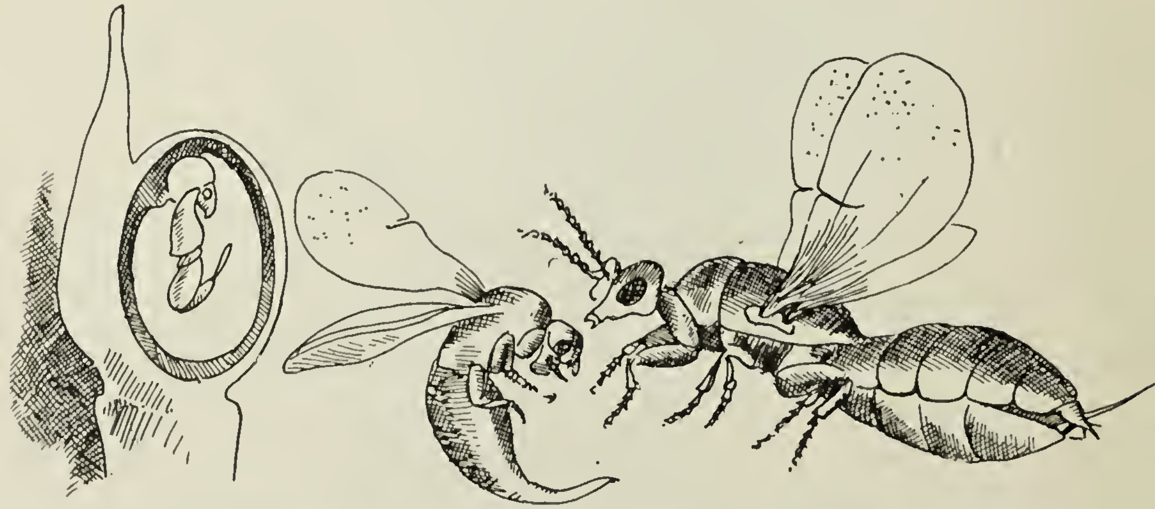


Fig. 471.—Longitudinal section through the hypanthodium of a Fig, showing the flowers in the interior.

The females remain a little longer in the galls and are there fertilised by the males. Afterwards they come out also, but only stay a short time within the cavity of the inflorescence, issuing from it as soon as possible into the open air. They crawl up to the mouth of the inflorescence, and in doing so come into contact with the pollen of the male flowers and get dusted all over the body, head, thorax, abdomen, legs, and wings. After squeezing through between the scaly leaves at the mouth of the inflorescence, and having at last reached the outside, they let their wings dry and then run off to other inflorescences on the same or on a neighbouring Fig-tree." If the latter, and the tree happens to be a "female tree" in an early stage of development, the result may be anticipated. The little visitors gain an entrance, perhaps tearing or even losing their wings on the sharp scales near the aperture, and, as they bustle about the hollow inflorescence, the pollen which they have brought with them gets dusted on to the stigmas, and fertilisation ensues.

Odorous flowers are of two kinds, fragrant and fœtid. The former, which are by far the most numerous, are chiefly visited by bees, butterflies, and moths; the latter, by carrion-flies and dung-beetles. *Arum crinitum*, says Hermann Müller, "attracts carrion-flies by means of its strong odour of putrid flesh. The smaller visitors are held fast by sticky hairs in the floral chamber and digested." He elsewhere affirms that the disgusting smell of the Marsh Calla (*C. palustris*) serves the double purpose of attracting carrion-flies and repelling injurious animals. This remark would be equally true of the gigantic *Rafflesia Arnoldi*, many Irises, and the remarkable Dragon Arum (*A. Dracunculus*).

Kerner, with characteristic thoroughness, has proposed to divide the floral scents into five groups, which he names the indoloid, aminoid, benzoloid, paraffinoid, and terpenoid scents—a distinct improvement on Dr. Robert Brown's threefold and somewhat empirical division into superodorants, subodorants, and inodorants. To the *indoloid* group belong



Blastophaga grossorum: the wasp fertiliser of the Common Fig.

Fig. 472.—The embryo insect in one of the ovules of the Fig. Fig. 473.—A later stage. Fig. 474.—The fully matured insect.

those volatile substances which arise from the decomposition of albuminous compounds, and diffuse into the atmosphere ; and in which one or several benzole nuclei are retained, as well as nitrogen. These compose the greater number of the fœtid scents; and the flowers in which they are developed "resemble animal corpses in their colouring, having usually livid spots, violet streaks, and red-brown veins on a greenish or fawn-coloured background." To the *aminoid* group belong those volatile substances which diffuse into the air and have an amine as their foundation; like the scents of Hawthorn, Ivy, and Mountain Ash. The *benzoloid* group comprise those scents which are formed from the so-called aromatic bodies, like oil of cloves and vanilla, and are found in the Honeysuckle, Wallflower, Pink, Violet, Lilac, and a host of other flowers. The *paraffinoid* scents include the vegetable acids and alcohol of those hydrocarbons which are known as paraffins, such as valerianic acid and oil of rue. They are found in the Rose, Valerian, Rue, Elder, etc. The last or *terpenoid* group consists of scents produced from ethereal oils destitute of oxygen, called terpenes; the well-known oil of lavender is one of them. They are usually developed in the tissues of the stems and foliage, but the Citron, Lavender, Thyme, Magnolia, and some other plants produce them in their flowers.

Fig. 475.—Indian Crocus.

Many flowers which are not cross-pollinated by insects, and some few that are, are quite odourless to man; though it does not follow of necessity that they are scentless to insects. To take an example: The flowers of the Virginia Creeper (*Ampelopsis quinquefolia*), in which we can detect no scent, evidently appeal to the olfactory sense of bees; otherwise it would be impossible to account for the readiness with which they find out the flowers, which have green corollas and are undistinguishable among the leaves at a little distance. As an instance

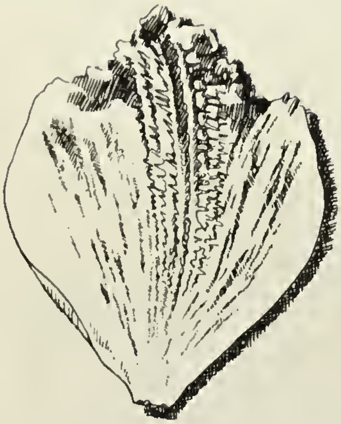


Fig. 476.—Lip of same spread out to show the fringes on its veins and the striped and barred markings.

of the power of smell in insects, Kerner relates that when, some years ago, the Aroid *Dracunculus creticus* from Cyprus was planted in the Vienna Botanic Gardens, though there were no carrion-flies in the vicinity, nor refuse matter of any kind to attract them, the large fœtid-smelling flower-sheath no sooner opened than it was freely visited by those insects, who came flying thither from every quarter. A captive Hawk-moth which the same distinguished naturalist let loose in the gardens at a distance of two hundred yards from a plant of Honeysuckle, flew directly, straight as an arrow, to the plant, and was found by Kerner, who had placed a cinnabar-red mark on the moth, hovering about over the flowers. Here again scent alone can have guided the insect.

Perhaps it will now be said, If scent and colour are the two chief means by which insects are attracted to flowers from a distance, what is to detain and reward them when the flowers are reached? In other words, What provision is made for their reception? This question is answered by completing the list of floral attractions which we have named. Two out of the six have been already dealt with. The remaining four are: Irregularity, Honey-guides, Nectar, and Pollen.

Irregularity is specially connected with the comfort of the insect. Labiate flowers, for example, provide a *landing-stage* for their visitors, as was pointed out in the case of the White Dead-nettle. The Calceolarias, which offer another typical form of irregular flower, not only provide a platform, but present their nectary to the humble-bee directly he has taken his seat; the Aristolochias, which are chiefly pollinated by flies, are furnished with conveniences in the way of perches and expansions for alighting, which clearly save the little guests a world of trouble. The Orchids (figs. 475 and 478) are provided with "all sorts of lobings and sinuses, fringes, pegs, and knobs on the lower lip, which serve as landing-stages and as fulcrums for further explorations to numerous flies, wasps, bees, humble-bees, and butterflies." So one might go on furnishing

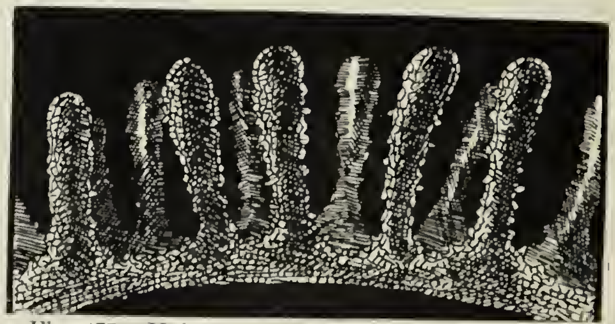


Fig. 477.—Hairs of a portion of two of the fringes of the lip (highly magnified).

examples indefinitely. The subject is inexhaustible, though whether the irregularity should be regarded as one of the causes of insect visits (the view adopted here, though for popular reasons only), or whether it is merely an effect, as Professor Henslow would persuade us, are questions which need not be discussed in this place.

The second provision in flowers for the reception of insects comprehends all those markings and accessory growths on the sepals and petals which are known as *Honey-guides* or *Path-finders*. The beautiful pencillings of flowers (spots, stripes, etc.), no less than their bright colours, serve, it is thought, to attract insects. Sprengel maintained nearly a century ago that the purpose of the marks is to guide to the nectary, a notion which Darwin for a long time scouted; but when the latter published his book on the *Effects of Cross and Self-fertilisation in the Vegetable Kingdom*, he had come round to Sprengel's view, and, indeed, defended it therein. In Darwin's opinion the case of the Pelargonium affords the best evidence that these marks have really been developed in correlation with the nectary. "The two upper petals," he writes, "are thus marked near their bases; and I have repeatedly observed that when the flowers vary so as to become peloric or regular, they lose their nectaries and at the same time the dark marks; when the nectary is only partially aborted, only one of the upper petals loses its mark. . . . It is, however, evident that insects could discover the nectar without the aid of guiding-marks. They are of service to the plant only by aiding insects to visit and search a greater number of flowers within a given time than would otherwise be possible; and thus there will be a better chance of fertilisation by pollen brought from a distant plant, and this we know is of paramount importance."

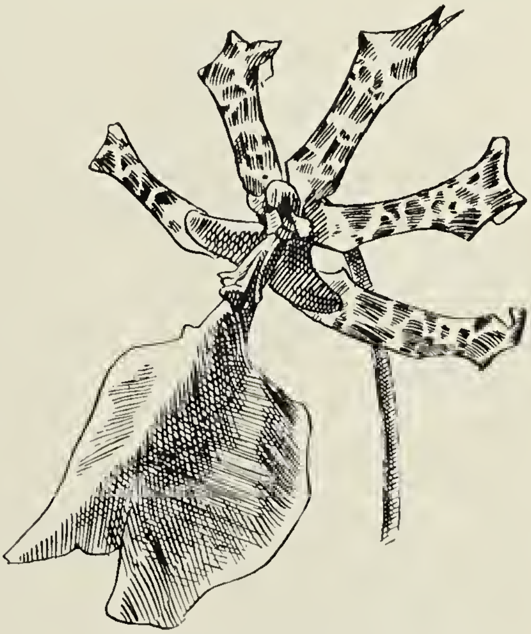


Fig. 478.—Flower of Tiger-striped Oncidium (*Oncidium tigrinum*).

Hairs, prickles, the grooves of petals, and warty protuberances may also serve as path-finders; and one or more of these features may be present in a flower in addition to the guiding-marks. This is the case in the beautiful Orchid known as the Indian Crocus (*Cœlogyne Lagenaria*, fig. 475), where the yellow fringes (figs. 476, 477) borne on the lilac veins of the lip of the flower, and the striped and barred markings on either side, act as path-finders. At the same time, it must not be supposed that all the stripes, spots, etc., of flowers are guides to the nectary. Probably in not a few cases their purpose is purely an æsthetic one. The Opium and Common Red Poppies, for example (*Papaver somniferum* and *Rhœas*), have no honey, and yet they are strikingly marked; and in many labiate flowers and Saxifrages (*e.g.*, *Saxifraga officinalis*, fig. 479) the marks are so small as to be hardly visible at a few paces—at least, to the human eye.

We come now to *Nectar*. Of all the attractions which flowers hold out to insect visitors, this is undoubtedly the chief. Nectaries are usually, though not always, situated deep down in the flower; and they present a variety of forms. In some flowers they have the appearance of small fleshy warts and pegs; in others they are grooved; in others ring-shaped; and, in the fourth case, hollowed out like spoons or shallow cups. These are the most common forms. The nectar itself "is not," says Professor Trail, "identical with honey, although, as furnished by many plants, it is the material from which bees make the latter. Analysis has shown the sugar of nectar to be, very generally, cane-sugar, while that of honey is grape-sugar, consisting of dextrose and levulose in equal proportions. The conversion of the cane-sugar is brought about by an admixture of salivary secretion at the time the nectar is sucked up. This conversion has been well made out in the case of bees; and since larger animals and man are known to convert cane-sugar into grape-sugar as an initial process in digestion, it is probable that butterflies and moths effect the same changes as the bee."

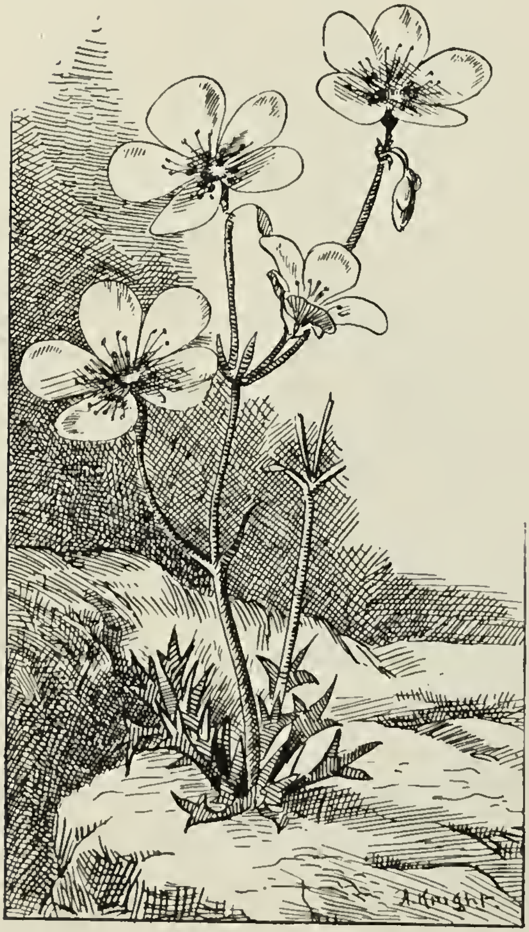


Fig. 479.—A species of Saxifrage (*Saxifraga officinalis*). The corolla is white with two violet spots at the base of each petal. The flowers are fertilised by short-lipped insects, especially flies.

At a meeting of the Linnean Society a few years ago some interesting specimens of honey were exhibited. Among these were the Eucalyptus honey from South Australia, which, like the plant from which it derives its properties, is valued as a febrifuge; and a quantity of the Arbutus honey from Turkey, which is said to produce drowsiness and sleep. The reddish honey of the Brazilian wasp, which is known to be actually poisonous, was also represented in the collection; as were the spring honey of Eastern Nepaul, which is noxious owing to the bees feeding on the nectar of the Rhododendrons; the honey of Trebizond, which is an irritant and intoxicant narcotic because of the poison of the Pontic Azalea and Rhododendron infused through it; a poisonous African honey obtained from a bee which feeds on Euphorbia flowers; and, lastly, a pale-looking honey foom Coorg, in Southern India, of which a very small quantity is said to produce severe headache, nausea, and prostration. Needless to add, the honey of our English bees is perfectly innocuous and wholesome.

The position of the nectary varies in different plants, and bears, as a rule, the most evident relation to the pollinating of the flower. In the Japan Lily (*Lilium speciosum*) the narrow grooves at the bases of the perianth form the nectary (fig. 480); and this is also the case in the Martagon Lily (*L. Martagon*), though here the nectary is more complicated in structure. The grooves (which are deeper than the grooves in the Japan Lily) are bordered by stiff hairs which rise up and arch over to form a tube, through which the nectar must be sucked, so that only long-tongued insects can get at it. In the Garden Nasturtium (*Tropæolum majus*) the sepaline spur of the calyx is the nectary; while in the Larkspur (*Delphinium*, fig. 481) and some closely allied species, the hollow petaline spur secretes the nectar. The two upper petals of *Delphinium elatum*, for example, lie close together so as to form a hollow cone, at the end of which is the nectar; whilst the spur, besides serving as a guide to the sucking-tubes of bees (the flower's chief pollinators), prohibits by its length the access of insects with shorter tongues.

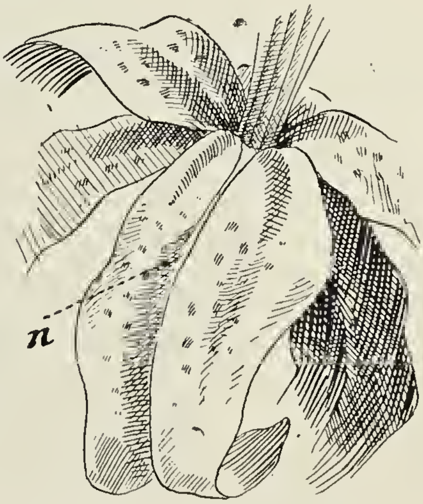


Fig. 480.—Grooved petaline nectary of Japan Lily.

In the Crowfoot family (*Ranunculus*) the nectar is protected by small scales at the base of the petals—one scale to each petal—as may be seen in the Buttercup (*R. acris*, fig. 482); while in the Common Barberry (*Berberis vulgaris*, fig. 483)—of which more hereafter—each of the

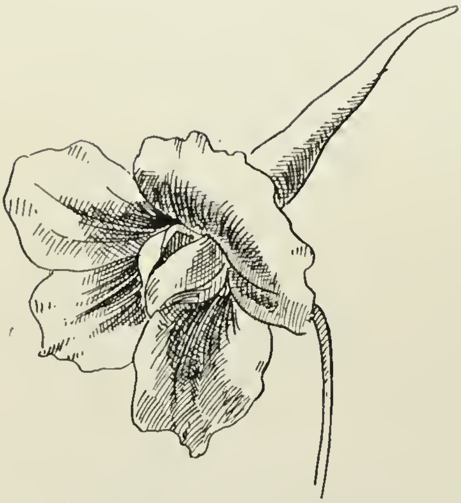


Fig. 481.—Flower of a Larkspur (*Delphinium grandiflorum*) with spurred calyx and corolla.

petaline nectaries is double. They differ also from the nectaries of *Ranunculus* in being thick and fleshy.

In the Violet (*Viola*) the correlation between the nectaries and the other organs of the flower is extremely interesting. The intricate arrangement of the several parts is a little baffling at first, but the drawings (figs. 484-489) will help to an understanding of the mechanism of the flower. The first sketch represents a single flower, laid open to show the two nectar-excreting appendages of the lower stamens, which, it will be noticed, are inserted in the spurred petal. Into this spur the liquid honey drops. The curious globular head of the stigma, with its hollow mouth-like chamber and tongue-shaped flap, is seen peeping above the triangular anthers, which surround the style collar-fashion; while the pear-shaped ovary is completely hidden by the broadened and cohering filaments of the stamens. The other drawings show these parts separately, as well as one of the two lateral petals, with its tuft of hairs. Both of the lateral petals are furnished with these hairs, which aid the bee in clinging to the flower. In some species of *Viola* the grooved part of the inferior spurred petal is also fringed with hairs, but they are for collecting pollen.

Now, when a bee wants to reach the honey in a flower—say, of *Viola tricolor*—it must insert its proboscis close under the capitate stigma, and this, as shown in the sketch, lies in the groove of the inferior petal. Into this groove the anthers shed their pollen, either of themselves or when the pistil is shaken by the bee, and hence the insect's proboscis, in passing down the groove to the spurred nectary, gets plentifully dusted with the yellow meal. As the proboscis is withdrawn, it shuts to the flap-like door of the stigmatic chamber, so that, for the nonce, no pollen can enter that cavity; but when the bee

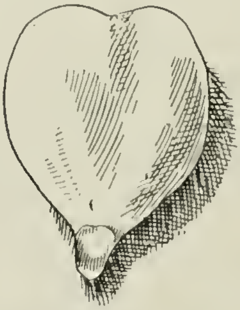


Fig. 482. — Nectary at base of petal of Buttercup.

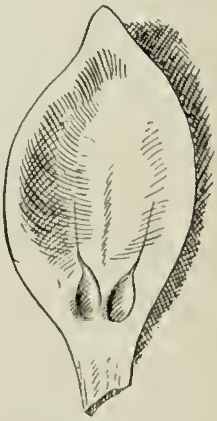
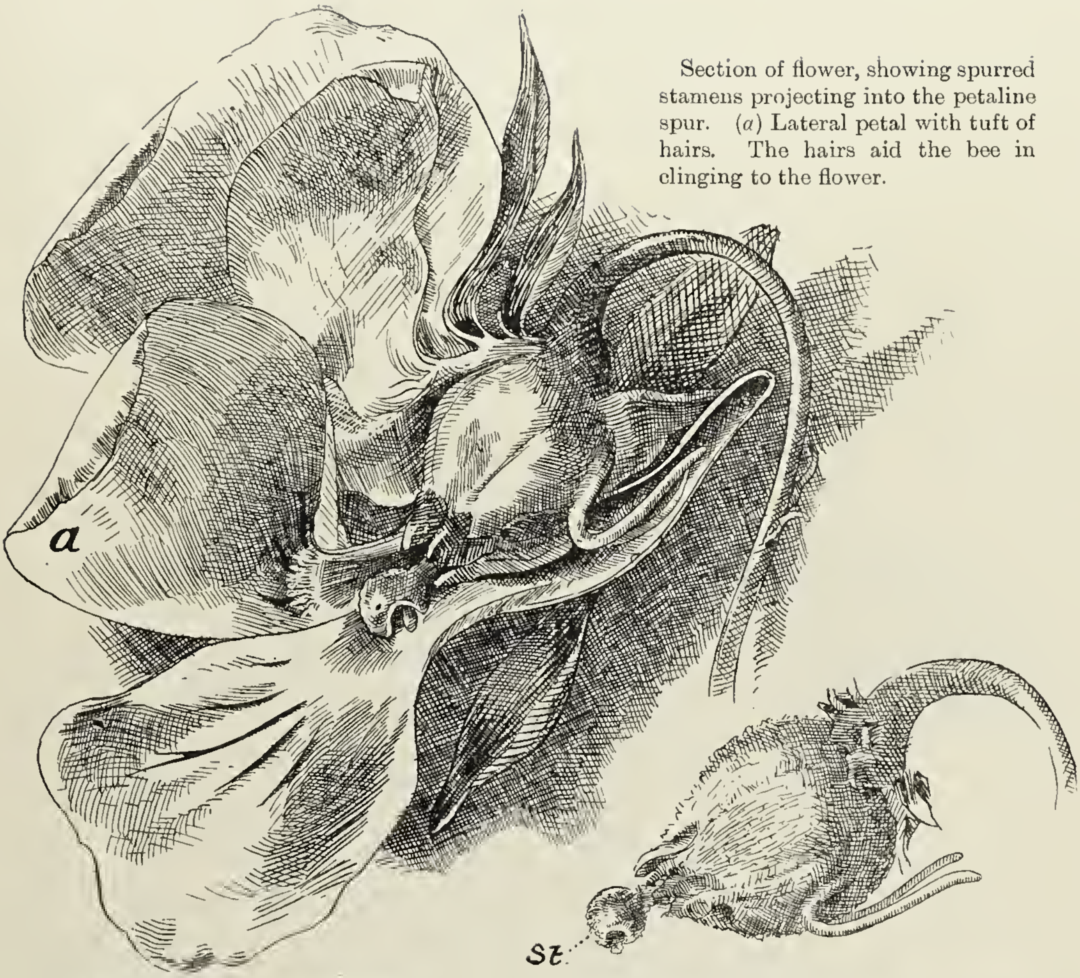
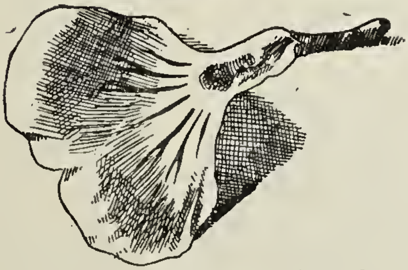


Fig. 483. — Nectaries on petal of Barberry.

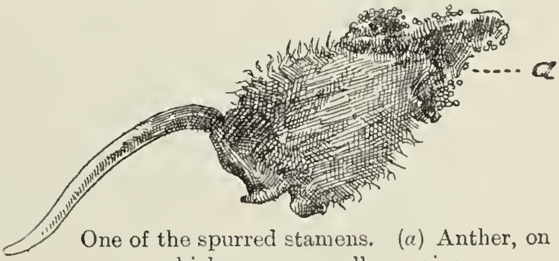


Section of flower, showing spurred stamens projecting into the petaline spur. (*a*) Lateral petal with tuft of hairs. The hairs aid the bee in clinging to the flower.

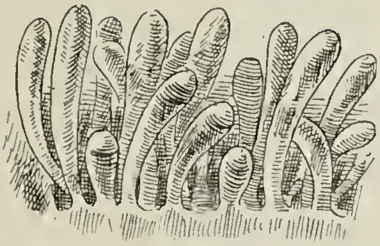
Stamens ensheathing the pistil, the stigma (*st*) of which projects.



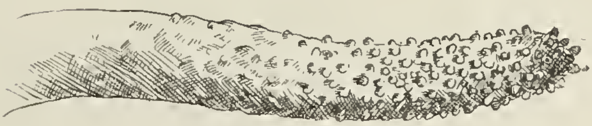
Sparred and grooved petal with pollen-collecting hairs.



One of the spurred stamens. (*a*) Anther, on which are some pollen-grains.



Hairs on the inferior grooved petal.



Nectar cells of the nectary.

FIGS. 484-489.—PARTS OF THE FLOWER OF A PANSY (*Viola tricolor*).

thrusts its head into the next flower, it leaves some of the precious dust on the upper surface of the flap, and thus cross-pollination is effected.

In the Alpine Liane (*Atragene alpina*) the grooved inner surface of the basal half of the stamens forms the nectary (fig. 490). "The pendulous violet flowers," says Hermann Müller, "only give up their honey to insects which can force asunder the numerous stamens, which are set closely in several whorls," and which, we may add, are held together on the outside by a whorl of stiff, erect, spoon-shaped staminodes* (fig. 491). Bees and humble-bees are among the few insects powerful enough for this work; and, in point of fact, they alone have been observed to pollinate the plant.

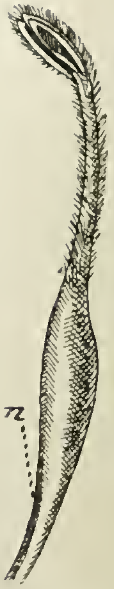


Fig. 490.—Stamen of *Atragene alpina* with grooved nectary (*n*).

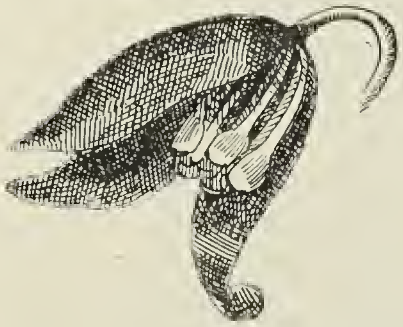


Fig. 491.—Flower of *Atragene alpina*. One of the sepals has been removed to show the petals with lineal bases and the stamens.

The nectaries of cruciform flowers (*Cruciferæ*) are usually glandular swellings at the base of stamens, the honey when secreted either remaining in drops upon the glands, or accumulating in the spaces between the stamens and pistil and in the sepaline pouches. The Cuckoo-flower (*Cardamine pratensis*)—of which Gerarde quaintly says, "it doth bloome in April and Maie, when the cuckoo doth begin to sing her pleasant notes without stammering"—is a good example (fig. 492). The nectar glands are the green fleshy cushions at the bases of the two shorter and the two aborted stamens (fig. 492, *b*), and the honey secreted by these glands accumulates in the pouched bases of the sepals. "In the young bud all the six anthers are turned towards the pistil, which projects above them. Before the flower

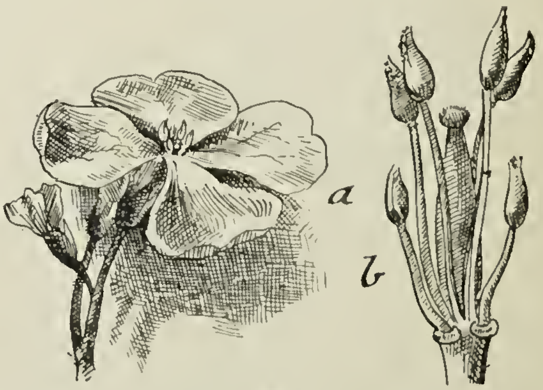


Fig. 492.—Cuckoo-flower. (*a*.) Expanded flower and buds. (*b*) Stamens, pistil, and nectaries of same.

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* A *staminode* is a barren stamen, more or less filiform in shape, placed either within or without the perfect stamens, but not furnished, like them, with anthers at the apex. H. Müller calls the staminodes of *Atragene alpina* "petals"; Kerner, "leaves"; Baillon, "staminodes"

opens the four inner stamens elongate and overtop the stigma, and make a quarter of a revolution outwards, each one towards the small stamen nearest to it; so that now an insect, in trying to reach the honey of one of the larger glands [those surrounding the bases of the shorter stamens], must rub its head or proboscis against the pollen-bearing surface of one of the taller anthers" (Müller).

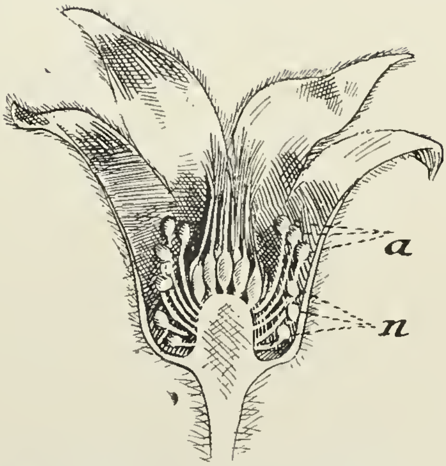


Fig. 493.—Section of Pasque-flower. (*a*) Stamens. (*n*) Nectaries.

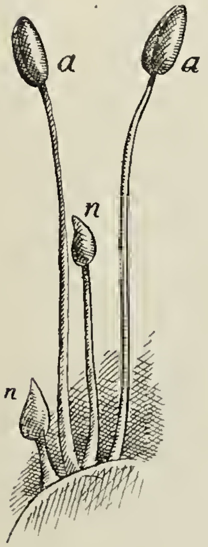


Fig. 494.—Stalked nectaries (*n*) of Pasque-flower. (*a*) Stamens.

In the Pasque-flower (*Anemone Pulsatilla*) we have an instance of stamens metamorphosed into nectaries—or perhaps it would be better to speak of them as rudimentary stamens, with shortened filaments, and glands instead of anthers (figs. 493, 494). In Papilionaceous flowers, like the Pea and Bean, the cohering fertile stamens secrete and store the nectar. They form a tube around the ovary, and the honey is poured into the base of the tube.

Very curious are the nectaries of the well-known Petty Spurge (*Euphorbia Peplus*), so common as a garden weed throughout the kingdom (fig. 495). The border of the cup-like involucre is studded with shining, crescent-shaped glands, which are much resorted to by flies, beetles, and other short-lipped insects, on account of the honey with which the glands are coated. They are, in fact, the nectaries; and by their prominence and accessibility they compensate for the inconspicuousness of the flowers. There is a nearly allied plant to the Spurges, a species of

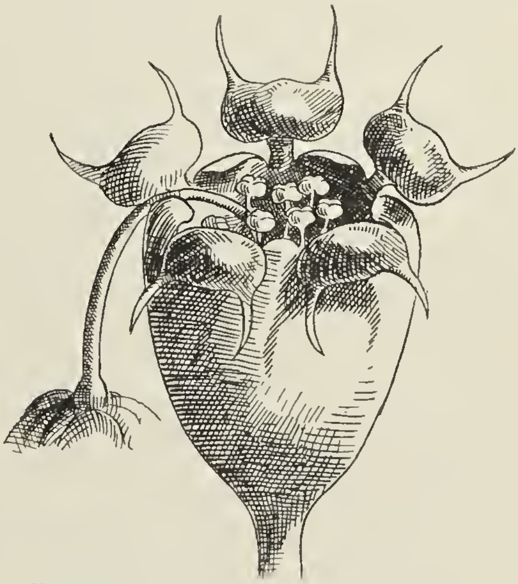


Fig. 495.—Portion of an inflorescence of Petty Spurge, showing horned nectaries of the involucre.

Dalechampia, which, according to Fritz Müller, attracts the insects which cross-pollinate it by means of a colourless resin secreted in special glands. This resin is collected by the insects (bees), and used in nest-building. In the Carrot (*Daucus*), Elder (*Sambucus*), and Ivy (*Hedera*) the nectary is also conspicuous, lying almost on the surface of the flower.

Ovarian nectaries are found in *Antirrhinum* (fig. 496), Speedwell (*Veronica*), the Common Comfrey (*Symphytum officinale*), and other plants. In the Spiked Speedwell (*V. spicata*, fig. 497) the fleshy base of the ovary secretes the honey, and the tube of the corolla holds it like a cup. A ring of long stiff hairs at the mouth of the tube shelters the nectar from rain. This is also the case with the Brooklime Speedwell (*V. Beccabunga*), which is freely visited by insects, particularly flies. The ovarian nectary of Comfrey is a white annular ridge, and in order to get at it the insect (usually a humble-bee) has to force apart the anthers, which form an inverted cone near the mouth of the tubular corolla. This releases the pollen, which falls upon the insect, and in due course is transferred to another flower.

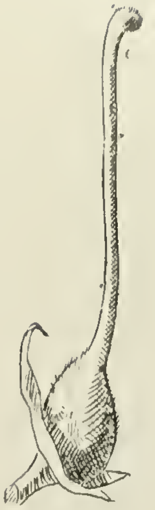


Fig. 496. — Pistil of *Antirrhinum majus* with ovarian nectary.

That nectaries have not always an exclusively utilitarian purpose is shown by the circumstance that they are sometimes found on the foliar parts of plants, at a considerable distance from the flowers. "It is always pleasant," says a writer in *Nature*, 1893, "to hear the contented hum of the bees amongst the young Laurel leaves [of *Cerasus lusitanica*]; for with no ulterior ends of their own the prosaic green bushes regale their friends with the sweets secreted by the yellow glands at the bases of their leaves, and, whatever may be said to the contrary, afford a triumphant proof that plants are not exclusively selfish and utilitarian, as we in our half-knowledge are sometimes apt to imagine." Certain species of *Prunus* (*e.g.*, the Cherry, *P. Cerasus*) produce nectaries in the form of small glandular swellings on their leaf-stalks (fig. 498), though the receptacular tubes of the flowers also secrete honey. The Bean, again (*Vicia Faba*), has nectaries on its stipules (fig. 499); so has the Seabrous Balsam (*Impatiens*

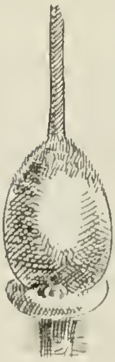


Fig. 497.— Annular nectary at base of ovary of *Veronica*. A drop of honey is seen to be exuding from the nectary.

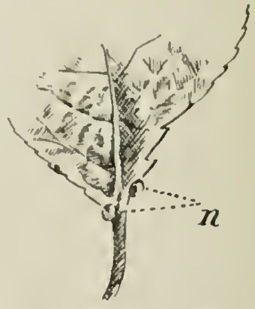


Fig. 498. — Nectaries at the base of leaf of Weeping Cherry.

tricornis). In the last-named plant these secretory glands appear to be an ingenious device for diverting creeping insects from the flowers. The little wingless marauders are turned aside in their ascent by the allurements spread out to them by the way. "They find," says Kerner, "drops of honey provided at the base of every foliage leaf equalling that of the flowers in quality, and surpassing it in quantity; besides which, it is nearer and more accessible. The honey-loving ants lick it up eagerly, and are content not to stray farther upwards."

That the quantity of nectar secreted varies greatly in different plants goes without the saying. While in some species the amount is so small as to be hardly discoverable, in others the blossoms literally flow with it. In the interesting Honey-flowers (*Melianthus*), a genus of strongly scented South African shrubs, the secretion is enormous. In *Melianthus major* an actual "rain of honey" pours from the cowl-shaped petals when the inflorescence is shaken. In the wonderful *Coryanthes*, a genus of tropical orchids, the nectareous fluid is secreted near the base of the stalk, and drips continuously into the helmet-shaped lip at the time of flowering. Upwards of an ounce of the fluid has been found in one of these receptacles.

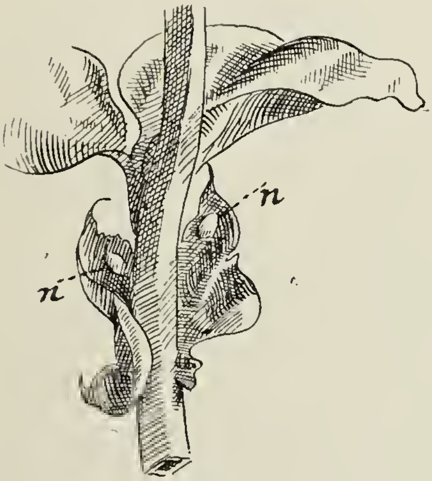


Fig. 499.—Nectaries (*n*) on stipules of the Common Bean.

So much for Nectaries. We have now considered five of the means by which insects are attracted to flowers with a view to the transference of pollen, and only one remains to be spoken of. The five already treated are Conspicuousness, Odour, Irregularity, Honey-guides, and Nectar; the sixth is the fecundating dust itself.

"*Pollen*," says Darwin, "contains much nitrogen and phosphorus—the two most precious of all the elements for the growth of plants—but in the case of most open flowers, a large quantity of pollen is consumed by pollen-devouring insects, and a large quantity is destroyed during continued rain. With many plants this latter evil is guarded against, as far as possible, by the anthers opening only during dry weather, by the position and form of some or all of the petals, by the presence of hairs, etc., and, as Kerner has shown in his interesting essay, by the movements of the petals or of the whole flower during cold and wet weather. In order to compensate the loss of pollen in so many ways, the anthers produce a far larger amount than is necessary for the fertilisation of the same flower. I know this from my own experiments on *Ipomœa*; . . . and it is still more plainly shown by the astonishingly small quantity produced by cleistogamic flowers, which lose none of their pollen, in comparison with that produced by the open flowers borne by the same plants; and yet this small quantity suffices for the fertilisation of all their numerous seeds. . . . The editor of the *Botanical Register* counted the ovules in the flower of *Wistaria sinensis*, and carefully estimated the number of pollen-grains, and he found that for each ovule there were seven thousand grains. . . . With *Hibiscus*, Kölreuter found that sixty grains were necessary to fertilise all the ovules of a flower, and he calculated that 4,863 grains were produced by a single flower, or eighty-one times too many." However, it is needless to pursue this part of the subject, as the ground has previously been traversed, and the facts are curious rather than essential.

In the majority of insect-fertilised flowers the pollen-grains are either rough or sticky, and thus are distinguished from the pollen-grains in wind-fertilised flowers, which are usually smooth. The reason of this is obvious. The rough and sticky kinds—"clinging pollen," as Kerner calls them—are adapted for clinging to insects visiting the flowers; the smooth kind—dusty pollen—is not less adapted for dispersion by the wind; for being easily taken up by the lightest breeze, and having no inequalities of surface, its resistance in passing through the air is of the slightest.

Few objects are so beautiful under the microscope as the pollen-grains of flowers. Not only do they vary greatly in their general forms, but their walls in many instances show the most exquisite sculpturing and patterns, which—if animals of the lower creation are as susceptible to beauty of form as man—must delight the eyes of the insects engaged in transporting the pollen from flower to flower. To draw attention to an example here and there: Each spherical grain of the Passion-flower (*Passiflora*) looks under a strong magnifying power like a beautifully chased Indian bowl (fig. 505). The figuring consists of three equi-distant circles, filled in with network, and having a sort of toothed outer ring to each circle. In *Lapageria*, *Cucurbita* (the Gourd family), and not a few other plants, the spherical grains are covered with spines (figs. 503, 510); whilst in the Mistletoe (*Viscum album*), White Water-lily (*Nymphœa alba*), etc., etc., the unevennesses are due to wart-like projections. The pollen-grains of *Cobœa scandens* (fig. 506) have a honeycombed appearance; those of *Mimosa* look like microscopic bales of merchandise, tightly tied with interlacing cords (fig. 509); in the Musk (*Mimulus moschatus*) they have a spiral form (fig. 507); in the genus of Nerine Lilies they are long and spindle-shaped (fig. 508); and in the Scots Pine (*Pinus sylvestris*) each grain is provided with a pair of bladder-like wings, which stand out from the grain like goggle-eyes (fig. 501). As the pollinating agent in this plant is the wind, the bladder-like structure is a most useful contrivance.

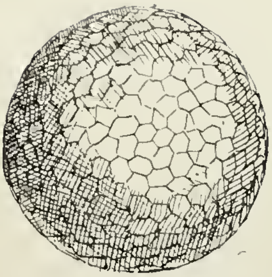


Fig. 500.—Japan Lily (*Lilium speciosum*).

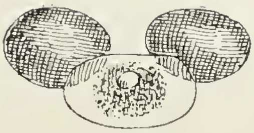


Fig. 501.—Scots Pine (*Pinus sylvestris*).

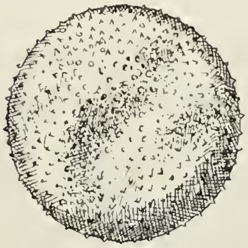


Fig. 503.—*Lapageria.*

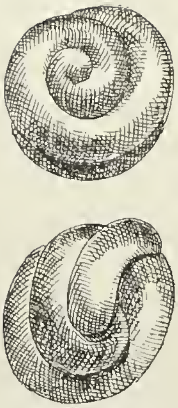


Fig. 507.—Musk.

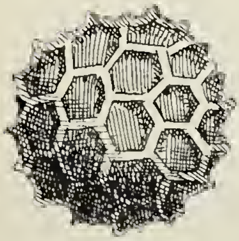


Fig. 506.—Climbing Cobæa (*Cobæa scandens*)

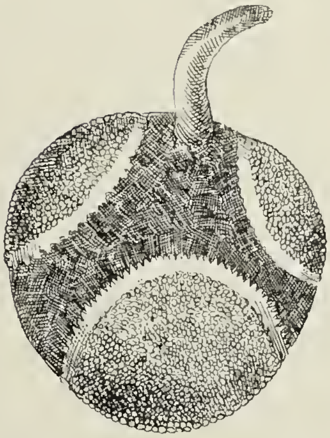


Fig. 505.—Passion-flower.

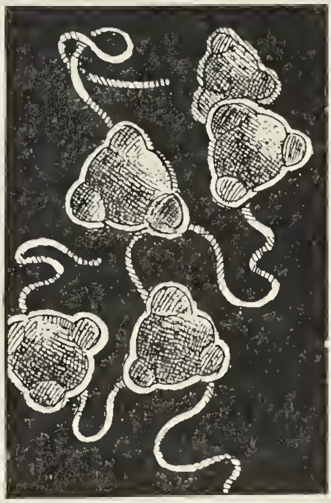


Fig. 502.—Evening Primrose.

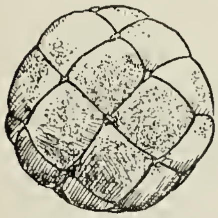


Fig. 509.—A species of *Mimosa.*

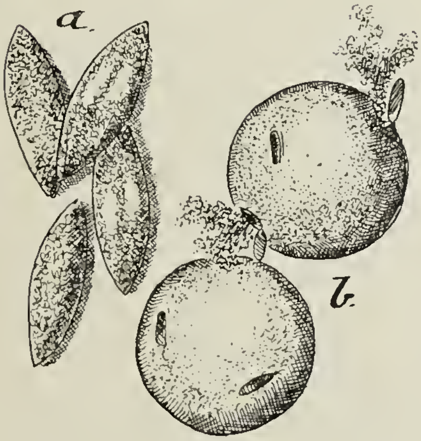


Fig. 508.—A Nerine Lily. (*a*) Dry. (*b*) Moistened.

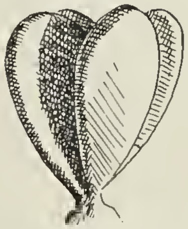


Fig. 504.—Indian Crocus (*Cœlogyne Lagenaria*).

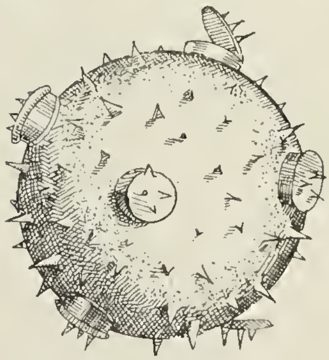


Fig. 510.—Pumpkin (*Cucurbita Pepo*).

Figs. 500-510.—Pollen-grains.

In a good many plants, as the Evening Primrose (*Œnothera biennis*), *Clarkia*, *Fuchsia*, etc., clinging pollen is strengthened by the presence of a sticky, structureless substance called *viscin*, which causes the grains to hang together in strings (fig. 502). The same substance appears to be the cementing vehicle in the majority of Orchids, where every pollen-sac (corresponding to an anther-lobe in ordinary flowers) contains an agglutinated club-shaped pollen-mass, known as a *pollinium*. The two pollinia commonly slope down to a little viscid gland or knob—the *rostellum*, which readily adheres to any object coming in contact with it, and which serves to mark the frontier between the solitary stamen * and the stigmatic surface below it (figs. 526-532, p. 329).

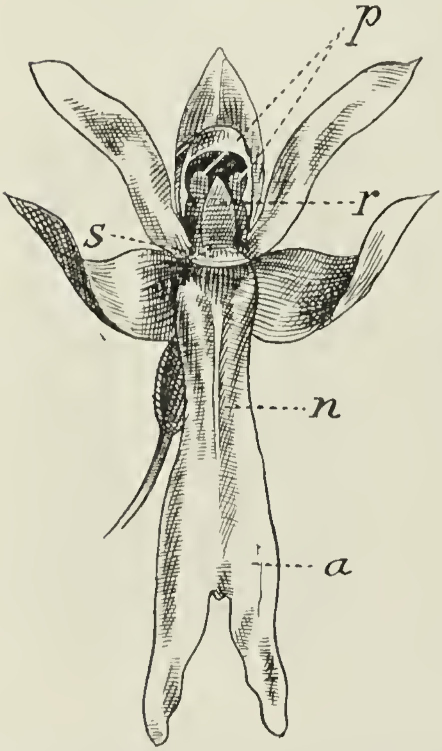


Fig. 511.—Flower of Common Twayblade. (*a*) Labellum. (*n*) Grooved nectary. (*s*) Stigma. (*r*) Rostellum. (*p*) Pollinia.

In the Common Twayblade (*Listera ovata*), as, indeed, in many other Orchideous plants—the rostellum plays an important part in the cross-pollination of the flower (fig. 511). In the species named this organ is flat and scale-like, and arches over the stigmatic surface. "Sprengel has correctly described," says Hermann Müller, "how small insects [chiefly beetles of the genus *Grammoptera*] regularly alight on the lower end of the labellum (*a*), and slowly creep upwards, licking the honey in the groove (*n*); when they have finished and raise their heads, they come in contact without fail with the slightly prominent edge of the rostellum (*r*). On the slightest touch, this exudes a small white drop of fluid, which reaches the apex of the pollinia (*p*), and hardening instantly, cements them to the object whose touch caused the exudation; and so in every flower which has not previously been visited, the insect visitor receives a new pair of pollinia. The insect flies away startled, and soon afterwards alights on the labellum of another flower, usually on another plant. The rostellum on first being touched, and while it exudes its drop of fluid, curves downwards so as partly to protect the stigma (*s*); but afterwards, while the groove of the labellum is secreting a fresh supply of honey, the rostellum gradually rises, leaving the way free to the stigma."

* Most species of *Orchideæ* are monandrous—*i.e.*, have only one stamen in each flower; but a few species are diandrous.

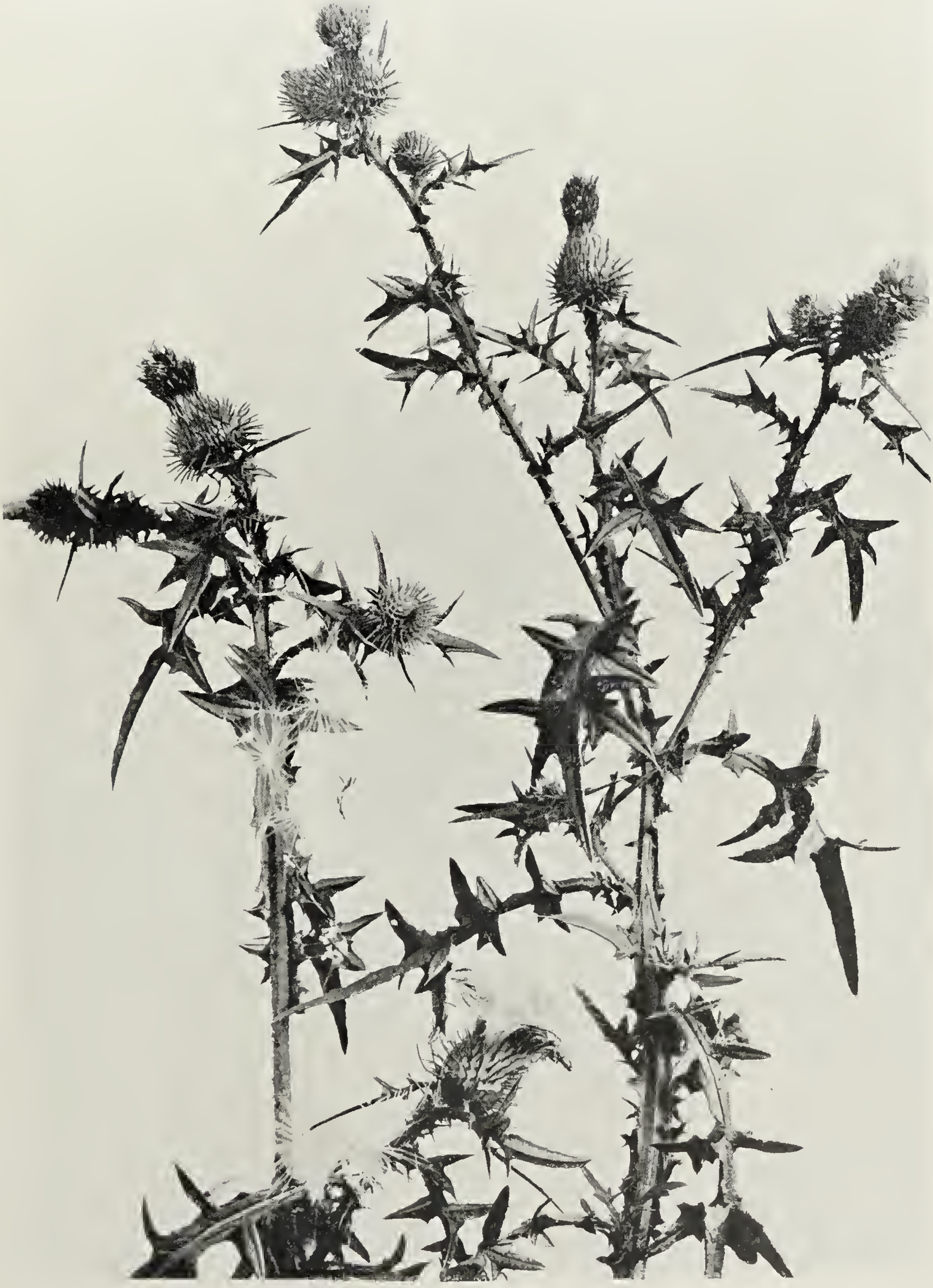


Photo by Henry Irving.

SPEAR THISTLE (*Cnicus lanceolatus*).

The florets of this plant are specially adapted for the visits of bees with long probosces, particularly humble-bees.

PLATE XVII.

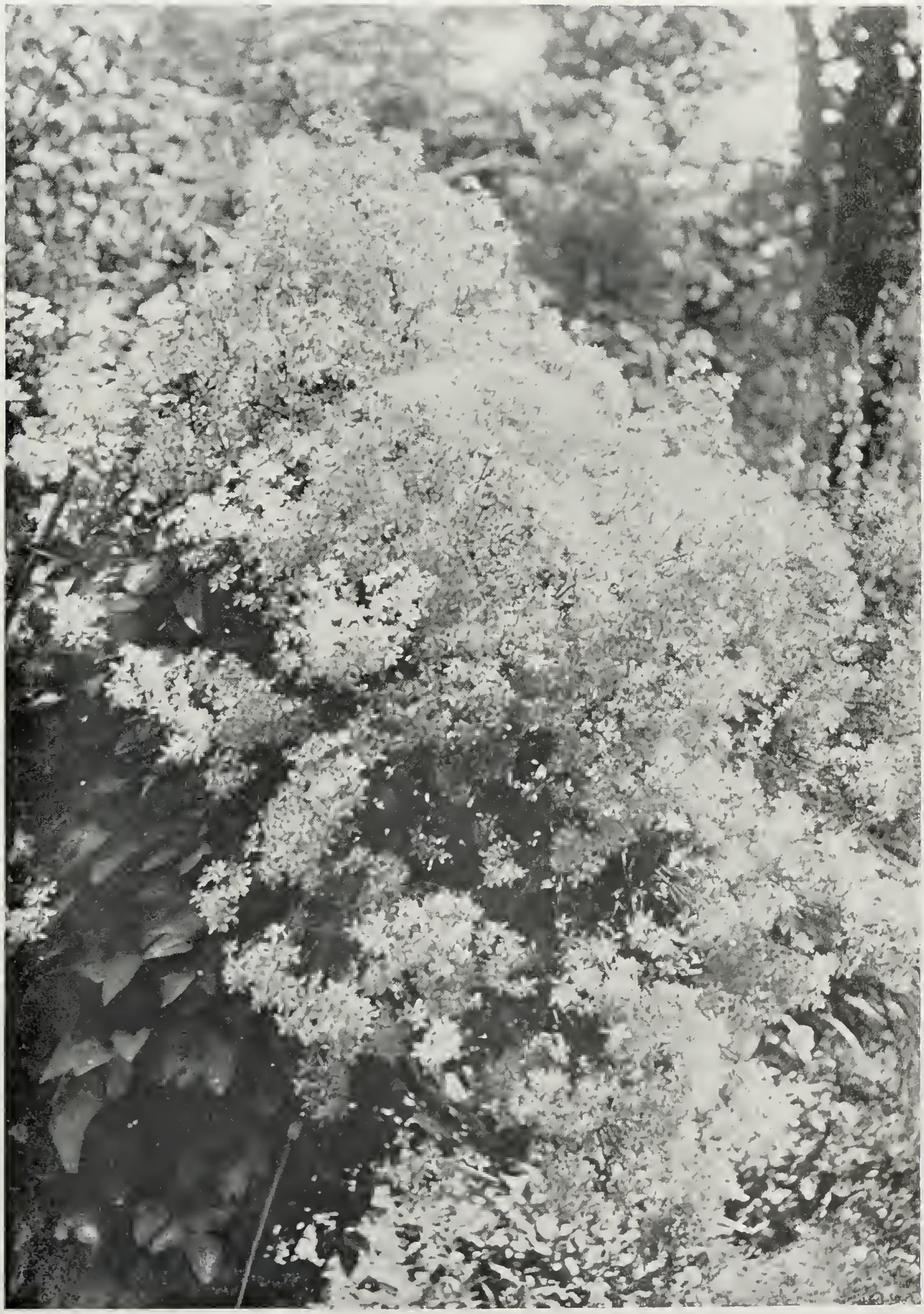


Photo by Walter Rossiter, Bath.

Densely Flowered Corymbs of a White, Sweet-Scented Species of Clematis.

Plate XXXVI

CHAPTER XII

SOME PLANT MARRIAGES AND THE GUESTS THAT ASSIST AT THE FUNCTION

> Rest, silver butterflies, your quivering wings;
> Alight, ye beetles, from your airy rings;
> Ye painted moths, your gold-eyed plumage furl,
> Bow your wide horns, your spiral trunks uncurl;
> Slide here, ye hornéd snails with varnished shells;
> Ye bee-nymphs issue from your waxen cells!
>
> ERASMUS DARWIN.

WE propose to speak in this chapter of a few of the contrivances by which the cross-fertilisation of flowers is brought about; a subject to which a considerable portion of Chapters X. and XI. may be regarded as an introduction. A good deal was there said about the means by which insects are attracted to flowers—those baits provided by the flowers in the way of bright or dull colours, nectar, pollen, etc., which bees and moths, flies, butterflies, and beetles find so irresistible; but as to what takes place in the flower during and after visitation comparatively little has been said. In returning to the subject it is not our purpose to confine our remarks as heretofore to the part which *insects* play in this important work. We propose to consider also the labours of other pollinating agents in the animal world, as snails and birds; and after that to say something of the transference of pollen by those two inanimate carriers, wind and water.

It has been observed by Dr. Ogle that in flowers which are cross-fertilised by insects, Nature does not hold out her baits one minute sooner than necessary. "The brilliancy, the scent, and the nectar are only furnished when the flower is ready for its guests and requires their presence; just as a thrifty housewife lights her candles when the first guest is at the door. The mature bud is furnished with no such attractions." The statement is interesting, and though it might be possible to name some insect-pollinated plants which display their attractions even in the bud, such plants should doubtless be regarded as exceptions to the rule.

We have seen that Darwin's pronouncement that "Nature abhors self-fertilisation," though not yet recognised (like Newton's law of gravitation or Boyle's law of the pressure of gases) as an established law of natural science, has yet some striking facts to support it; and more of these facts will come before us in the present chapter. We have seen, too, that the curious and often minute correlations in certain flowers are in view of their cross-pollination by insects; and that the parts of the flower which sustain the weights, strains, thrusts, etc., are admirably modified and strengthened, as though to facilitate and encourage the guests by whose visits the crossing is to be effected. Of this subject also the present chapter will furnish additional illustrations.

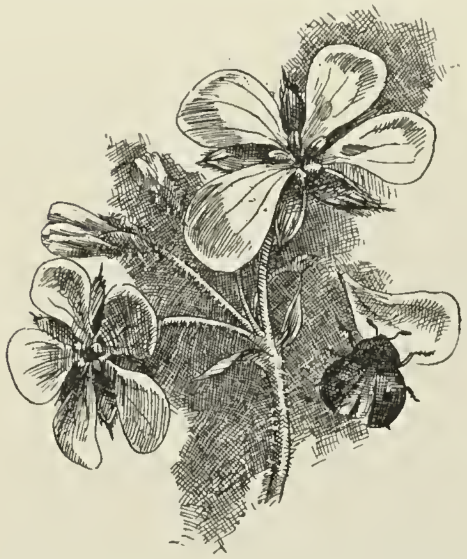


Fig. 511.—Hemlock Stork's-bill, with seven-spotted Ladybird clinging to a petal which its weight has dislodged.

Yet it must not be thought that *all* cross-pollinated flowers are so careful of their guests. In some instances it is really surprising that the visitors remain at all, so little are they encouraged. Watching one day some seven-spotted ladybirds (*Coccinella septempunctata*) licking honey from the pretty rose-pink flowers of the Hemlock Stork's-bill (*Erodium cicutarium*), Hermann Müller met with an amusing illustration of this fact. While seated on a petal the insect would apply its mouth to one of the nectaries at the base; and then all at once the petal would break off, and either precipitate the beetle to the ground or leave it clinging to the next petal. "In the former case it would keep on its way round the flower, and perhaps pull off all five petals, one after another; but when it fell it was always at once on its legs again, running to another stalk of the same plant to climb up anew. I saw," adds this careful observer, "one beetle fall four times to the ground without growing wiser by experience" (fig. 511).

How irritating, again, must be the treatment offered to the gnat-pollinators of the Aristolochias, who (as we were seeing in another chapter) are held prisoners in the blossoms for a period not far short of sixty hours! Much the same sort of thing goes on in the flowers of the Indian stove-plant *Ceropegia elegans*, though in this case the insects (small flies) are not imprisoned for so long a time, and instead of getting dusted with pollen they leave the flower with the pollinia in their proboscides. In the Dutchman's Pipe (*Aristolochia Sipho*), a native of North America, escape is prevented by the smoothness of the perianth-tube and its curvature at both ends, but when the midges have fulfilled their allotted task, the perianth withers and they are thus enabled to crawl out.

Analogous devices are not unknown even among our commoner British plants. The little Cuckoo-pint (*Arum maculatum*, figs. 294, 295) is certainly guilty in this respect. The construction of the flower-clusters—whose prisoner guests are those tiny moth-like flies, the Psychodæ—has been briefly explained in Chapter X. (p. 231). The flies pass in by the wide entrance formed by the upper part of the spadix-ensheathing spathe and descend to the lower chamber (fig. 294), which becomes their prison. A number of reflexed hairs (rudimentary flowers) encircle the spadix in the upper part of the chamber, forming a palisade, which, though not preventing ingress, cannot be repassed by insects within the chamber, who are bewildered by the sloping rigid bars when they try to fly towards the light. Below the hairs is a closely packed ring of male flowers, and lower still, at the very base of the spadix, a surrounding cluster of female flowers. These mature first, and announce the fact to the Psychoda by emitting a foul ammoniacal odour, which is very attractive to those insects. They flock to the banqueting-house in great numbers, and if they have brought pollen from other arums, fertilise the stigmas, which thereupon wither. The little visitors at the same time receive payment for their services in nectar, of which each stigma yields a single drop. Afterwards the anthers shed their pollen, which falls upon the chamber floor, and the flies get well dusted. Their services being now required by the plant no longer, the palisade of hairs shrivels up, and the prisoners are set free.

The imprisonment of *bidden* guests is not however a frequent occurrence among plants. It is by no means a usual thing for the front door to be locked on a visitor when he enters a flower. Nevertheless, the treatment which these unconscious benefactors receive is often sufficiently rough and unhandsome; and perhaps no plants are greater offenders in this respect than those rajahs of the Vegetable World, the Orchids, to which we shall refer again shortly. For the present let us examine one or two of our common flowers, in which the contrivances for securing cross-fertilisation, though exceedingly curious, are simpler than those of the flowers named.

We may start with what has been aptly called the *brush and piston mechanism* of the cultivated Pea (*Pisum sativum*), which supplies a type rather common, though with varying modifications, among papilionaceous flowers. In an earlier chapter (p. 263) we described the several

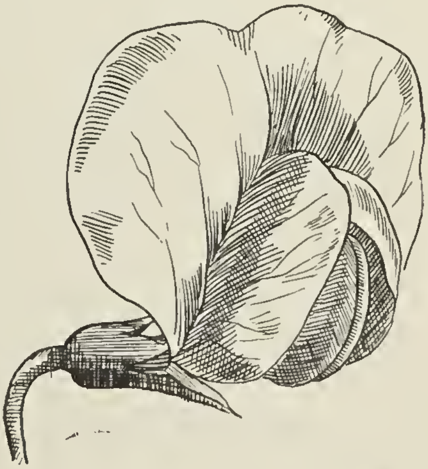


Fig. 512.—Flower of Common Pea.

parts of a flower of the Pea, and showed the adaptation of those parts to its chief pollinators—bees. We saw that the stamens and pistil are contained in the keel or carina of the blossom, those two cohering petals which protect the anthers from pollen-feeding insects, and that the alæ or wings—*i.e.*, the two lateral petals—afford a platform for the bee guest, as well as serve as a lever to depress the keel. The last fact is of much importance owing to the effect attending such depression—an effect which will be explained in a moment.

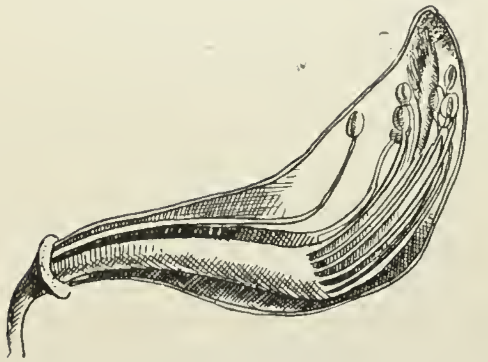


Fig. 513.—The same, after removal of calyx, wings, and standard, and one of the coherent petals of keel. In the hollow of the remaining petal are seen the stamens and pistil, and (in the conical cavity above the anther) the pollen.

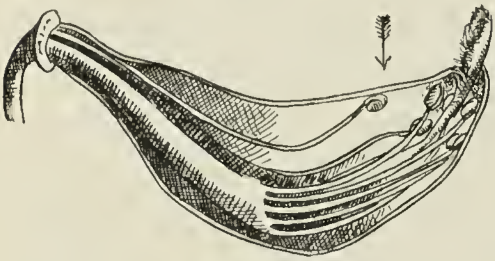


Fig. 514.—The same, depressed in the direction of the arrow. When such depression is caused by the weight of a bee, the pollen-covered style-brush is forced out of the conical cavity and strikes against the belly of the insect.

We will suppose that fig. 512 represents a pea-blossom which is about to be visited by a bee. The flower is giving forth its seductive odour; the bright standard is fully spread; a supply of nectar has flowed into the staminal tube; and the anthers have discharged their moist, sticky pollen into the conical part of the keel, thereby covering the tiny brush with which the end of the style is provided. All is ready. Presently the bee alights; and as its weight falls upon the wings of the flower the keel is depressed. At once the piston mechanism comes into play, for the style, being a fixture, does not yield to the depression, and so the pollen-laden style-brush is thrust through the apical hole of the keel. Here it comes in contact with the breast of the bee, which gets plentifully smeared with the pollen. When the insect has sipped its fill of nectar, it flies off to another flower, the stigma of which is pretty sure to receive some of the pollen from the last flower. Thus cross-fertilisation is effected.

What is known as *percussive mechanism* is admirably illustrated in the Salvias, that genus of labiate flowers to which belongs the Common Sage of our gardens (*Salvia officinalis*). The remarkable feature in this form of mechanism is the *rocking part of the stamens*, which, as we saw when speaking of the male organs of plants (p. 268), is a specialised form of the connective. The connective is, in fact, a curved bar attached to the filament of the stamen by a movable joint, and running transversely to it. The upper part of this curved bar is the longer and bears the anther (fig. 517); while the stubby lower part has no anther and is finished off with a knob. The flowers are diandrous and the stamens are so close together that the knobs, which stand just in the open jaws of the corolla, almost touch. Tucked away in the upper hooded portion of the corolla is the style; but its forked stigma is closed during the first stage of the flower, its services not being required till later. The nectaries are situated deep down in the tube of the corolla, near the ovary, so that when a bee alights on the landing-stage (fig. 518) it must push its head right into the jaws of the flower before it can get at the honey. Here the knobs of the two connectives block the way, and both of these knobs get struck by the bee's head. This is the act of percussion which puts the machinery in motion. Instantly the connectives swing round on their hinges, and the pollen-bearing anther-lobes are brought down upon the bee's back, besprinkling it with the yellow dust. Should the next flower visited be in the female stage (fig. 519) the pistil will present a different appearance from that described above. No longer tucked away out of sight under the hood, the style will have elongated and curved over, and the two forks of the stigma will have opened wide, and be hanging just at the suitable height for picking off the pollen from the bee's back. Clearly the old game of quintain, so great a favourite with our forefathers, is not yet obsolete!

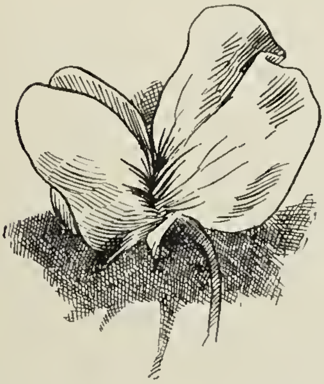


Fig. 515.—Flower of Sweet Pea (*Lathyrus odoratus*) before fertilisation.

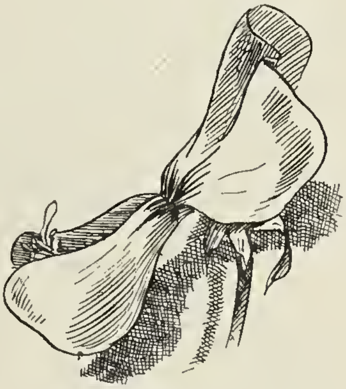
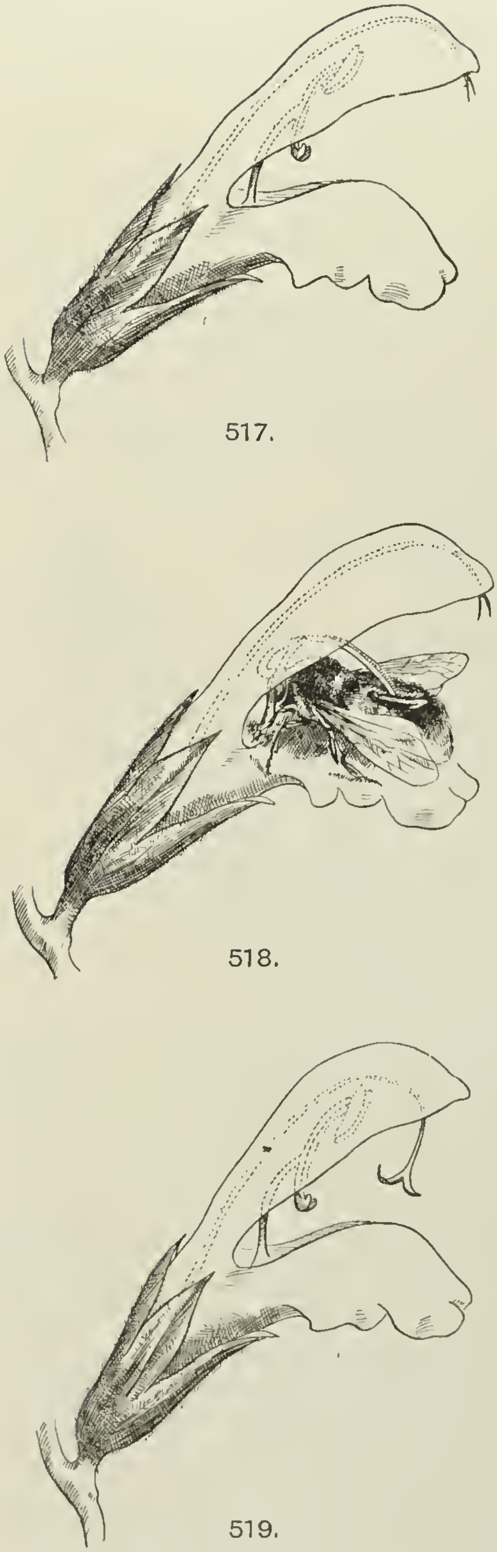


Fig. 516.—The same, after fertilisation.

Irritability in the organs of flowers, particularly in the essential organs (andrœcium and pistil), is almost always due to mechanical contrivances and connected with cross-fertilisation. Witness the irritable stamens of the Common Barberry (*Berberis vulgaris*, fig. 520), which spring up and scatter their pollen on the head of the bee as it thrusts its proboscis into the nectar. Witness, too, the yet more remarkable stamens of the American Laurel (*Kalmia latifolia*), a flower the pollination of which has been very fully described by Professor Beal, of Michigan. In this case the anthers are forcibly held down in the saucer-shaped corolla by means of little pockets, the filaments being thus bent back and transformed into so many springs. "It is interesting to watch the operations of a humble-bee upon the flowers," says another American observer, Professor Asa Gray. "The bee, remaining on the wing, circles for a moment over each flower, thrusting its proboscis all round the ovary at the bottom; in doing this it jostles and lets off the springs, and receives upon the under side of its body and its legs successive charges of pollen. Flying to another blossom, it brings its pollen-dusted body against the stigma, and commonly revolving on it as if on a pivot while it sucks the nectar in the bottom of the flower-cap, liberates the ten bowed stamens, and receives fresh charges of pollen from that flower while fertilising it with the pollen of the preceding one." If flowers of Kalmia are protected from insects (the experiment was tried by Mr. Beal with coverings of fine gauze), they wither, drop off, and set no seed; the reason being that no stamen gets liberated of itself while fit for action (figs. 522, 523).

A curious method of clamping the pollen-masses (pollinia) of flowers to the feet of insects is to be noticed in the Asclepiads, and has been distinguished as *clip mechanism.* In *Asclepias Cornuti*, for example, the connective of each pair of pollinia is a hard substance "capable of holding any small delicate object by gripping it like a clip" (fig. 524); and these clips are so disposed in the flower that when an insect visits it for honey a foot is pretty sure to get caught by one of the clips. On trying to free itself the insect brings away the pollinia, which then, by a remarkable



517.

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Figs. 517-519.—Fertilisation of Sage.

twisting of the ligulate strands which connect them with the clip, are brought close together (fig. 525). This facilitates their insertion by the insect in the stigmatic chamber of a new flower, where, by a breaking of the strands, the leg and its burden part company. The clips, however, remain attached to the insect; and wasps and flies have been caught with as many as eight of these vegetable pincers fastened to a single foot.

The Brazilian Asclepiad, *Araujia albens* (*Physianthus albens* of gardeners) has acquired an evil reputation outside its own country and been nicknamed the "cruel plant," for causes connected with its floral mechanism. In Brazil the cross-pollination of its tubular flowers is effected chiefly by humble-bees, which find no difficulty in pulling themselves free when their feet get caught in the slit-like notches that guard the way to the pollinia; and thus the pollen-masses get carried off to new flowers. In other parts, however, as Michigan, Italy, and the Orange River Colony,

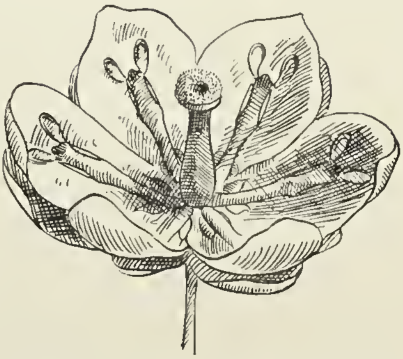


Fig. 520.—Flower of Common Barberry, showing the stamens lying in the petals of flower.

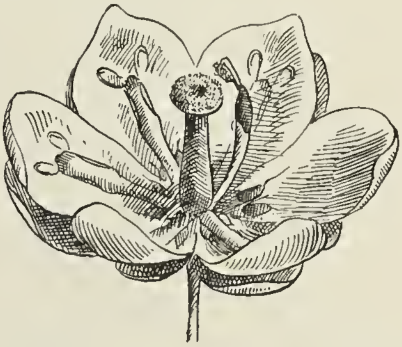


Fig. 521.—The same, showing one of the stamens discharging its pollen.

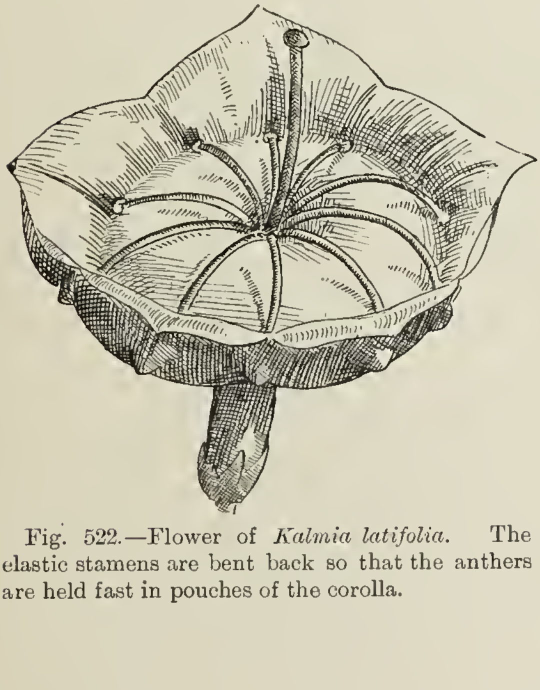


Fig. 522.—Flower of *Kalmia latifolia.* The elastic stamens are bent back so that the anthers are held fast in pouches of the corolla.

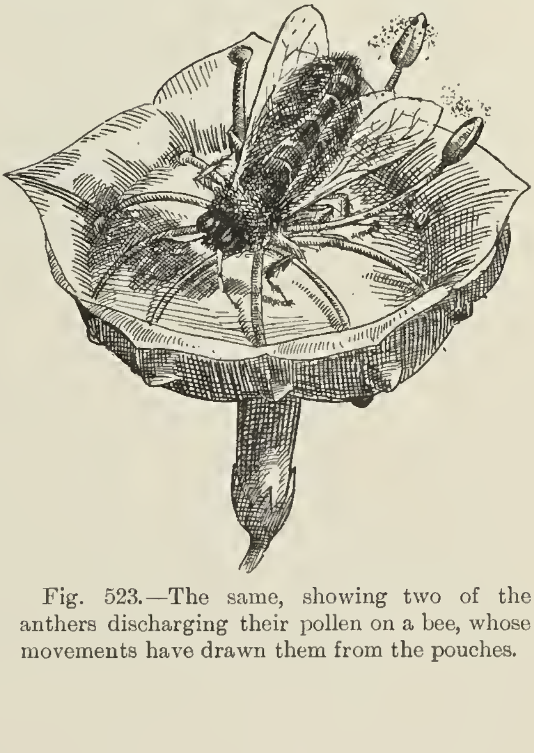


Fig. 523.—The same, showing two of the anthers discharging their pollen on a bee, whose movements have drawn them from the pouches.

the plant is visited in large numbers by moths, whose complete ignorance of the mechanism of the flowers becomes their ruin. Thrusting their probosces in the slits to get at the honey, they are held fast, and all their struggles to liberate themselves only fix them tighter. With their heads in the tubes of the corollas, and their bodies and wings projecting, they die a lingering death.

We come now to the Orchids. The parts of an Orchid flower have been described in the previous chapter, where also the pollination of a British orchid, *Listera ovata*, the Common Twayblade, is briefly described (p. 320). Perhaps it will not be taken amiss if, before going farther afield, we direct attention to another British species—the Spotted Orchis (*Orchis maculata*)—the pollination of which differs from that of the Twayblade in some important particulars.

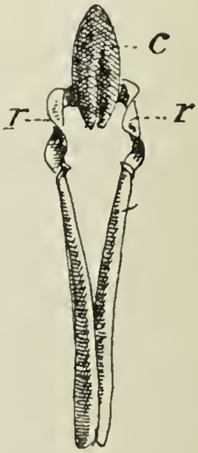


Fig. 525. — The same at a later stage: the broad, flattened sides of the pollinia brought together by a twisting of the ligulate strands (*r*). (*c*) Clip or corpusculum.

It will be seen (fig. 531) that the sepals and two upper petals of this flower arch over the anthers, lobes, and rostellum, and that the inferior petal or lip affords an excellent landing-stage for visitors. This petal is prolonged backwards into a hollow spur, which takes the place of a nectary; for though it secretes no free honey, its delicate and succulent tissue is much prized by flies and bees. The pouched rostellum, which contains a brownish and viscid matter, projects into the mouth of the spur and also overhangs the two stigmatic surfaces; while the only perfect anther (the others are mere rudiments) stands immediately above it. Now an insect visiting the flower and dipping its head into the spur, necessarily strikes against the rostellum. In so doing the pouch gets ruptured, and as the ruptured membrane curls back, it brings into view two viscid discs or balls in close connection with the caudicles (stalks) of the pollinia (fig. 532). These instantly adhere to the intruding object, and when the insect withdraws its head, the two pollinia are seen to be sticking up upon it like a pair of clubbed horns. Moreover, the cement, which has remained viscid under its membranous covering perhaps for many hours, now hardens with great rapidity—a wonderful and indispensable provision, for were

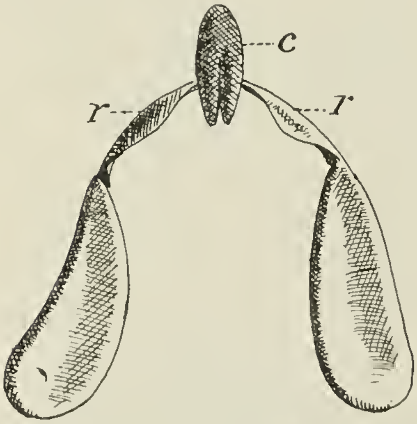
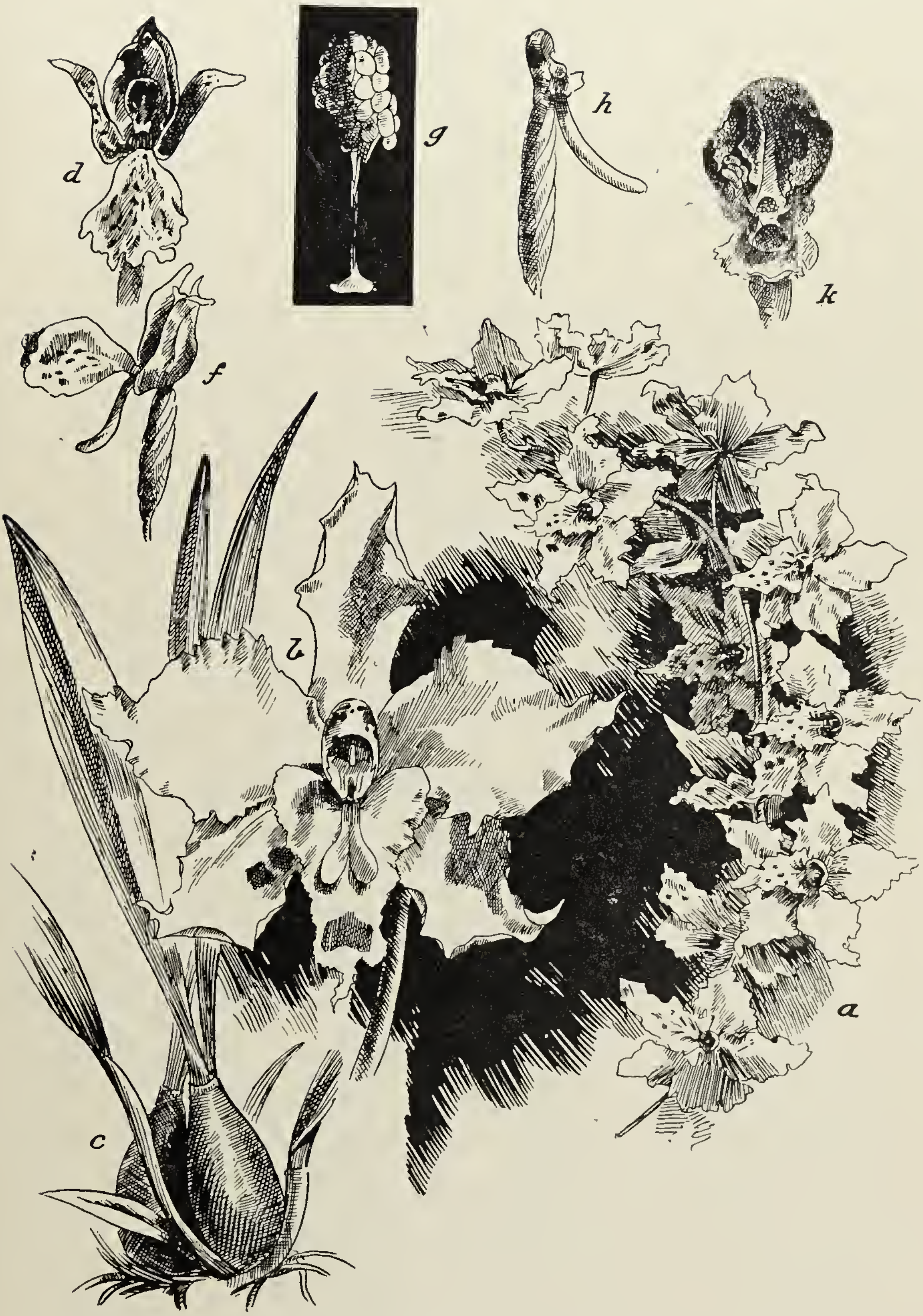


Fig. 524.—Pollinia of *Asclepias Cornuti* immediately after removal from flower.



Some Orchidaceous Plants (*see* pp. 328-30).

(*a*) Flowering branch of *Odontoglossum Alexandræ.* (*b*) Single flower of same. (*c*) Pseudo-bulbs and leaves of same. (*d*) Spotted Orchis (*Orchis maculata*). (*f*) Side view of same, showing the twisted ovary. (*g*) Pollen-mass of *Orchis maculata* as seen under a low power of the microscope. (*h*) The flower after removal of perianth, showing tube, twisted ovary, pollen sac, and rostellum. (*k*) Front view of column with ruptured pollen-sacs, showing a few pollen-grains still remaining therein.

[*To face p.* 329.

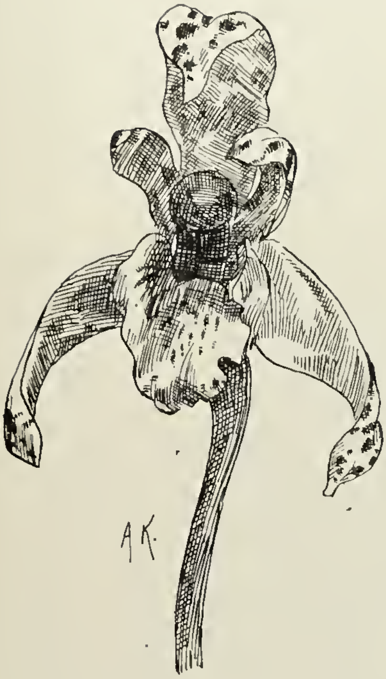


Fig. 527.—The same (front view).

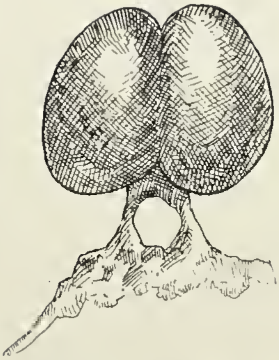


Fig. 530.—The pollinia (greatly magnified).

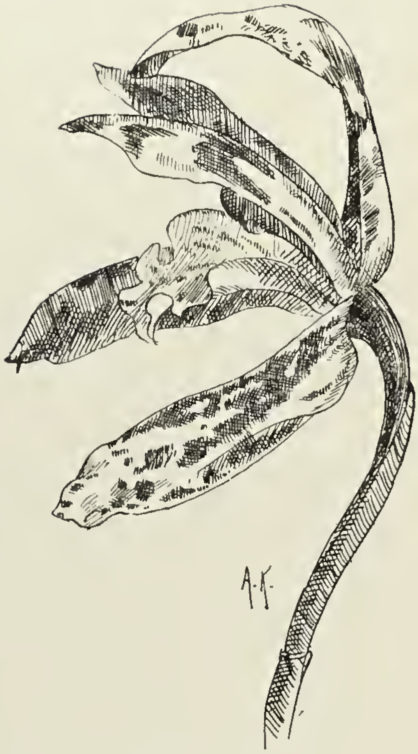


Fig. 526.—*Maxillaria picta* (side view).

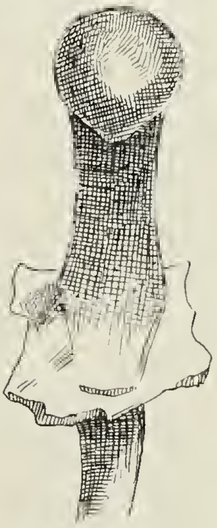


Fig. 528.—Column of same after removal of petals (magnified).

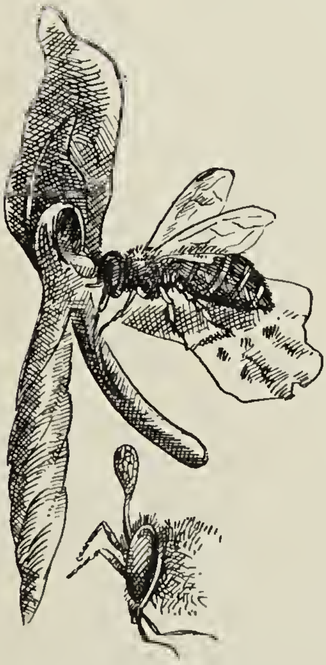
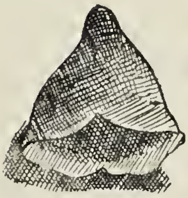


Fig. 532.—Part of flower of Spotted Orchis.



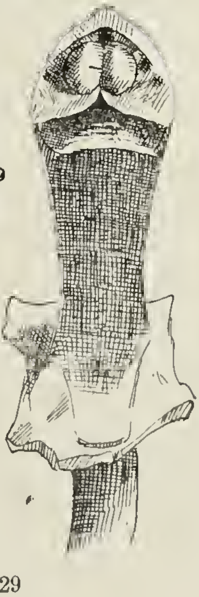


Fig. 529.—Column with the cap removed showing stigmatic chamber and the pollinia, the latter partially concealed by two curtains.

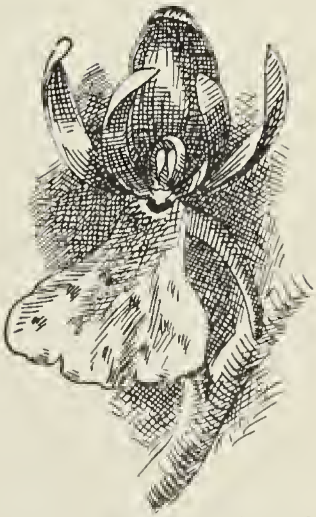


Fig. 531.—Flower of Spotted Orchis.

the pollinia to fall sideways or backwards, their usefulness for purposes of cross-fertilisation would be at an end. Nevertheless, at their present angle they are equally useless, for, on visiting another flower, what can happen but that the insect will push them back into their old position? This danger is obviated by a beautiful contrivance, which Darwin thus explains in his classical work on Orchids: "Though the viscid surface remains immovably affixed, the apparently insignificant and minute disc of membrane to which the caudicle adheres is endowed with a remarkable power of contraction . . . which causes the pollinium to sweep through about ninety degrees, always in one direction—viz., towards the apex of the proboscis—in the course on an average of thirty seconds. . . . Now, after this movement and interval of time (which would allow the insect to fly to another flower) . . . the thick end of the pollinium is exactly in position to strike the stigmatic surface." Surely if evidence were wanted for the argument of Design in Nature, you have it here! We may add that Darwin is speaking of the Early Orchis (*O. mascula*); but his remarks apply equally to the Spotted Orchis.* The plants are closely related, and the manner of their fertilisation is the same in all essentials.

The genus *Orchis* is not the only group of orchidaceous plants containing species which are unprovided with true nectaries. The wonderful *Catasetum tridentatum* and its female, the *Monachanthus*,† are further examples (fig. 533). The cup or *labellum*—which in other species is usually the nectar receptacle—is singularly inverted in the varieties specified, and thus is altogether precluded from fulfilling that purpose. Yet, since the sexes stand on separate plants, insects must be attracted to the flowers in order to secure fertilisation; and insects, like beings of a higher order, will not work except for reward. Darwin was the first to point out that the labellum itself, which in these varieties is thick and fleshy and of "a pleasant nutritious taste," probably affords food to its insect visitors, and thus answers the purpose of nectar, just as do the tubes in *Orchis maculata* and *O. mascula*. His surmises have been abundantly verified.

Darwin regarded the genus *Catasetum* as "the most remarkable of all Orchids," and with good reason. For these are the Orchids which possess the extraordinary power of forcibly expelling their pollinia when a certain part of the flower—the horns or *antennæ* of the column (fig. 535, *an*) —is touched. Observe how the band or pedicel of the pollinium (*b*), which connects the disc (*d*) with the pollen-masses (*p*), is curved about the projecting rostellum This pedicel is in a high state of tension. When either of the tapering sensitive projections or antennæ is touched (and bees visiting the flower to gnaw at the labellum inevitably come in contact with it), "the edges of the upper membrane of the disc," says Darwin, "which are continuously united to the surrounding surface, instantaneously rupture, and the disc is set free. The highly elastic pedicel then instantly flirts the heavy disc out of the stigmatic chamber with such force that the whole pollinium is ejected, bringing away with it the two balls of pollen, and tearing the loosely attached spike-like anther from the top of the column (fig. 536). The pollinium is always ejected with its viscid disc foremost."

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* Indeed, to two other British Orchids—viz., the green-winged Meadow Orchis (*O. Morio*) and the Marsh Orchis (*O. latifolia*).

† So dissimilar is the female flower of *Catasetum tridentatum* from the male that it was long regarded as belonging to a distinct genus, *Monachanthus*, and styled *M. viridis*. Singularly enough, *C. tridentatum* also bears hermaphrodite flowers, which differ no less in appearance from the male and female forms than do those from one another. Hence the plants producing them were classed with a third genus, *Myanthus*, under the specific name *barbatus*. But a plant was discovered bearing flowers of the three supposed genera on one spike, and so the true state of things was recognised, and revision made accordingly.

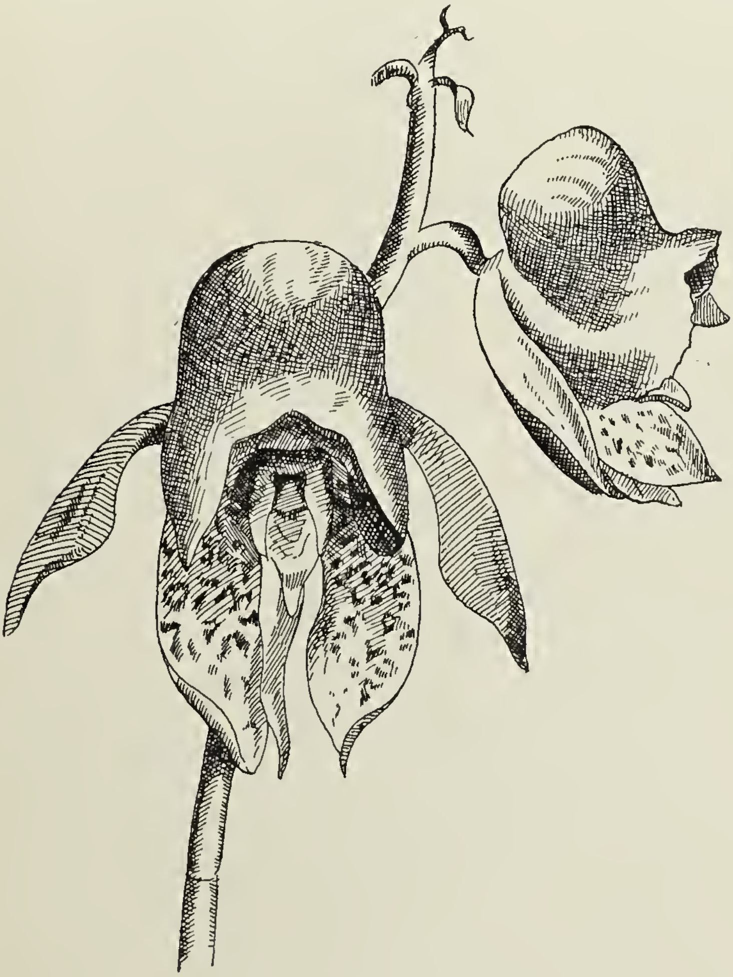
Fig. 533.—*Catasetum tridentatum.*

The force of the discharge will sometimes send the pollinium a distance of two or three feet. One of the attendants at Kew Gardens told the writer that he was once severely rated by a lady who had been struck in the face by the pollinium of *Catasetum saccatum*, and had come to him with the disc yet sticking to her cheek! Such experiences are not uncommon. Lord Avebury saw a flower of *Catasetum callosum* precipitate its pollinium a distance of three feet, when it hit a pane of glass and adhered to it. "From the large size of the flower, more especially of the viscid disc, and from its wonderful power of adhesion,” says Darwin, “we may safely infer that the flowers are visited by large insects. The viscid matter sticks so firmly when it sets hard, and the pedicel is so strong (though very thin and only one-twentieth of an inch in breadth at the hinge) that to my surprise it supported for a few seconds a weight of 1,262 grains—that is, nearly three ounces; and it supported for a considerable time a slightly less weight.” Needless to say, no effort which an insect thus encumbered could exert would remove the disc and pedicel; “but the caudicles are ruptured without much difficulty, and thus the balls of pollen would be left on the viscid stigmatic surface of a female flower.”

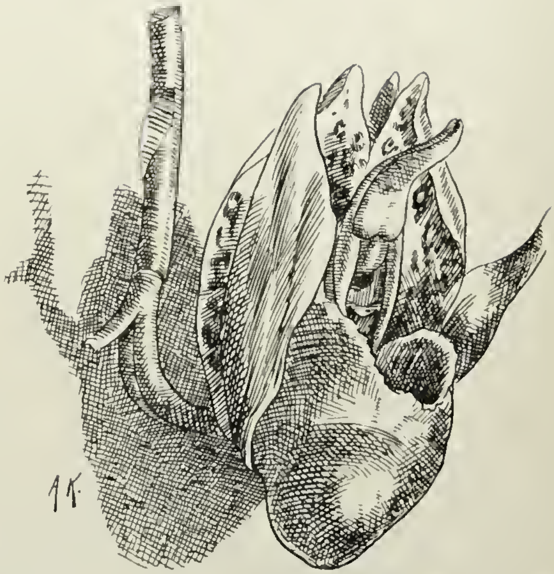
Fig. 534.—Flower of *Catasetum tridentatum* (inverted).

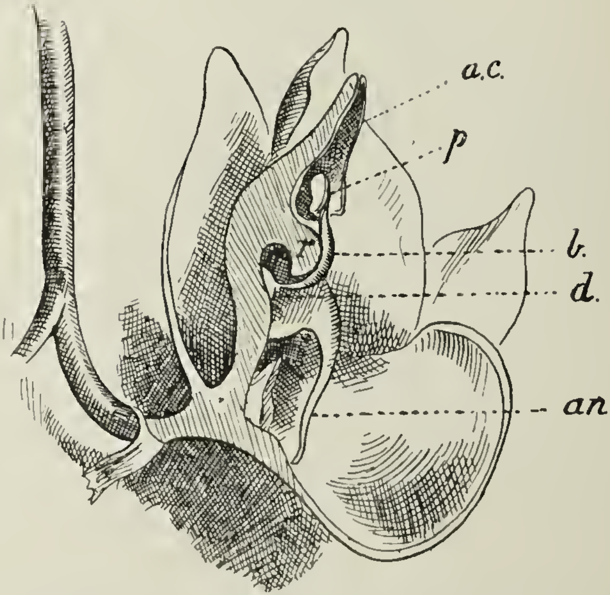

Fig. 535.—The same in section. (*a c*) Anther case. (*p*) Pollen-masses. (*d*) Viscid disc. (*b*) Band connecting pollen-masses with disc. (*an*) One of the antennæ.

In striking contrast to the Catasetums are those Orchids which secrete great quantities of nectar, like *Coryanthes*. The sweet fluid secreted by the strange-looking horns of *Coryanthes macrantha*, for example, drips so plenteously into the bucket-shaped portion of the labellum at the period of flowering that it half fills the bucket—indeed, would *quite* fill it, were it not that the receptacle is provided with an overflow spout! Above the bucket is a hollow chamber, walled and ceiled with fleshy ridges and provided with two side entrances. “The most ingenious man,” says Darwin, “if he had not witnessed what takes place, would never have imagined what purpose all these parts serve. But Dr. Crüger saw crowds of large humble-bees visiting the gigantic flowers

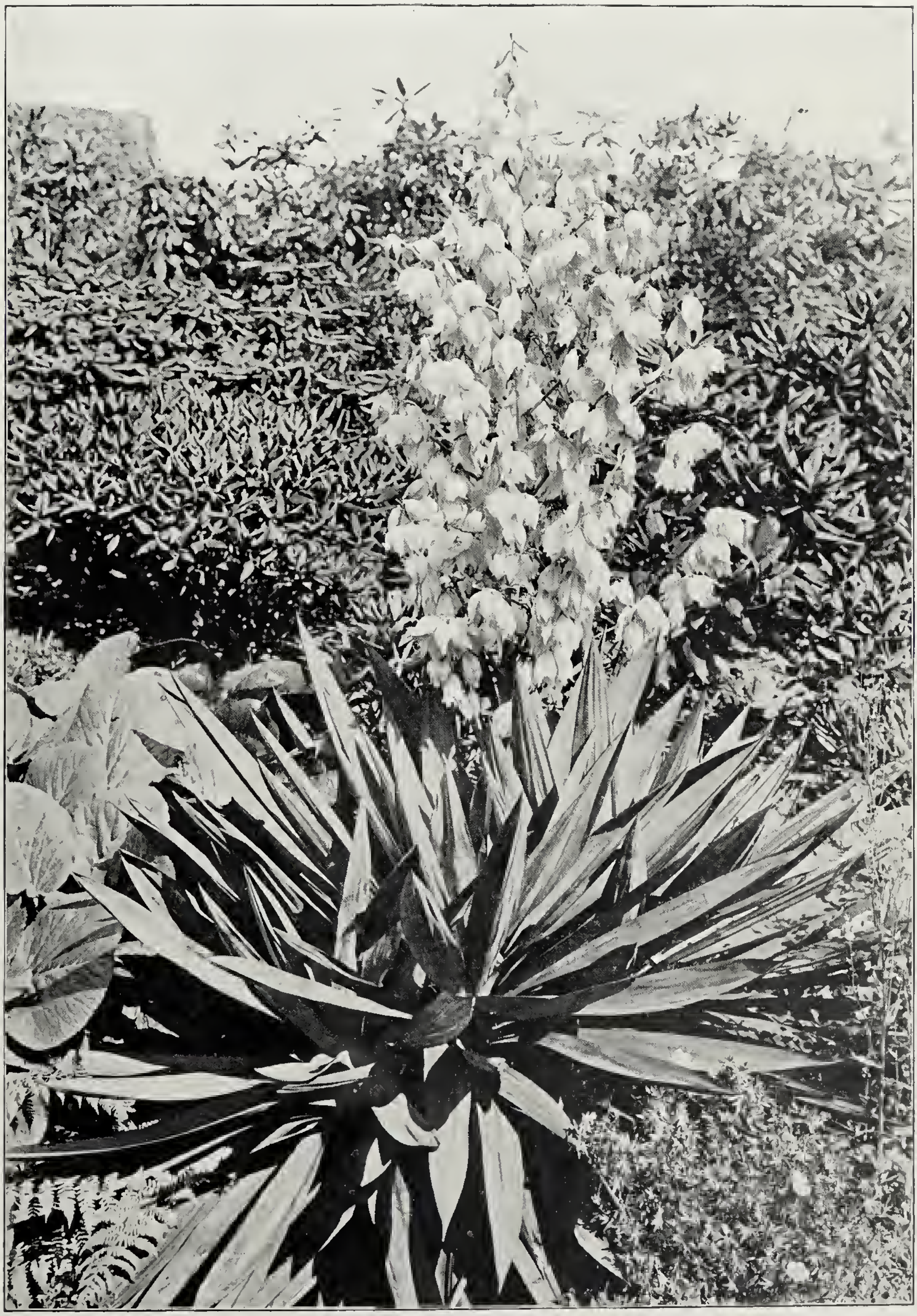

Photo by H. Irving.

Yucca-plant (*Y. gloriosa*).

This plant is cross-fertilised by insect agency in a manner which makes it one of the wonders of the vegetable world. The process is fully described in a later chapter.

Plate VIII.

of this orchid—not in order to suck nectar, but to gnaw off the ridges within the chamber above the bucket; in doing this they frequently pushed each other into the bucket, and their wings being thus wetted, they could not fly away, but were compelled to crawl out through a passage formed by the spout or overflow. Dr. Crüger saw a continual procession of bees thus crawling out of their involuntary bath. The passage is narrow, and is roofed over by a column, so that a bee, in forcing its way out, first rubs its back against the viscid stigma, and then against the viscid glands of the pollen-masses. The pollen-masses are thus glued to the back of the bee which first happens to crawl out through the passage of a lately expanded flower, and are thus carried away. When the bee, thus provided, flies to another flower, or to the same flower a second time, and is pushed by its comrades into the bucket, and then crawls out by the passage, the pollen-mass necessarily first comes into contact with the viscid stigma, and adheres to it, and the flower is fertilised. Now at last we see the full use of every part of the flower—of the water-secreting horns, of the bucket half full of water, which prevents the bees from flying away, and forces them to fall out through the spout, and rub against the properly placed viscid pollen-masses and the viscid stigma."

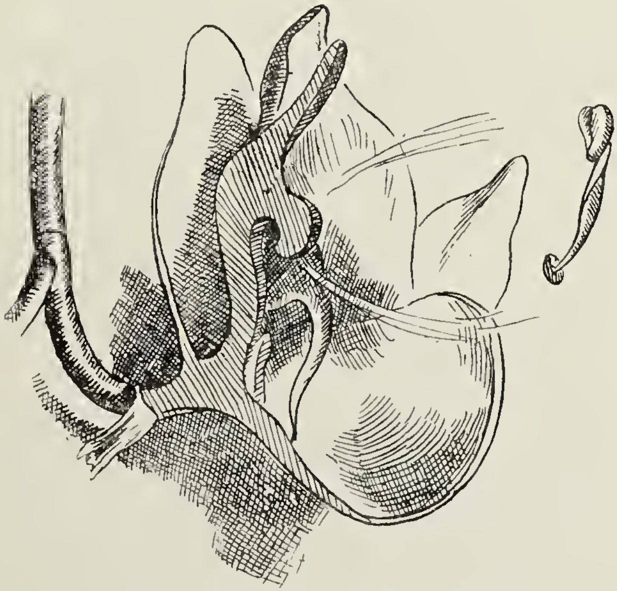

Fig. 536.—The same expelling its pollinia.

A gardener of long experience in Orchid culture informs us that *Stanhopea Haseloffi*, which belongs to an allied genus, is cross-pollinated in the same way as *Coryanthes*, save that the half-drowned bees *fall out* of the bucket, and strike against the pollinium in falling.

Our remarks on insect-pollination are now almost at an end; but no sketch of the subject, however slight, would be at all satisfactory which omitted a reference to the fertilisation of the Yucca-plant. It is nearly thirty years since Professor C. V. Riley, of Missouri, first announced the method of pollination of the Yuccas by a little white moth, which he christened *Pronuba Yuccasella.* Since that time much has been written on the subject, and in 1892 Dr. Riley published a valuable monograph on Yucca pollination, from which we have gleaned most of the particulars given below. The monograph, which extends to sixty large octavo pages, is included in the third annual report of the Missouri Botanical Garden.

The Yuccas are a very interesting genus of plants of the lily family, comprising numerous species and even sub-genera, all characterised by anthers not reaching anywhere near the stigma; so that fertilisation unaided can take place only by the merest accident. These plants, in fact, depend for their very existence on certain little white moths, belonging to the important group *Tinæina*, and to the genus *Pronuba*. Thus the Yuccas afford an instance—apparently the only known instance—of plants which are dependent on a single species for pollination.

The common garden Yuccas of the States are forms of *filamentosa*, and their white-winged pollinator is the commoner Yucca moth, *Pronuba Yuccasella* (fig. 538). During the daytime this moth, either singly or in pairs, may be found resting with folded wings within the half-closed flowers. After sundown it is to be seen flitting swiftly from plant to plant and flower to flower; the dusky nature of the hind wings and of the under surface of the front wings almost completely off-setting and neutralising, when in motion, the upper silvery whiteness of the latter. This is the male insect. The female is busily at work most of the time in the flowers; for on her devolves a double duty, which leaves no leisure for these nocturnal flittings. As a part of the maternal task of continuing her race, she must act as foster-mother to the plant in order to ensure a proper supply of food to her larvae, which, as we shall presently see, feed on its seeds. Her activity begins soon after dark, and consists at first in assiduously collecting a load of pollen. She may be seen running to the top of one of the stamens, and bending her head down over the anther, stretching her maxillary tentacles, which are wonderfully modified for the purpose, to the fullest extent; and using her palpi to scrape the pollen from the anthers towards the tentacles (fig. 540).

After gathering a sufficient supply, and shaping it into a pellet twice or thrice the size of her head, she sets off for another flower, leaving the despoiled blossom to be pollinated by some other individual of her race. On entering the new flower, she takes up a favourable position, and after resting motionless for a short time, plunges her lance-like ovipositor into the soft tissue of the pistil, and conducts her first egg to its destination. Mark what follows. No sooner is the ovipositor withdrawn than the moth runs up to the top of the pistil, thrusts the pollen into the stigmatic funnel, and rams it down effectually with a to-and-fro motion of her head (fig. 539). If, as is commonly the case, another egg is deposited in the same pistil, and after that a third, each act of oviposition is succeeded by a fresh act of pollination; but on each occasion a different notch of the style is selected,

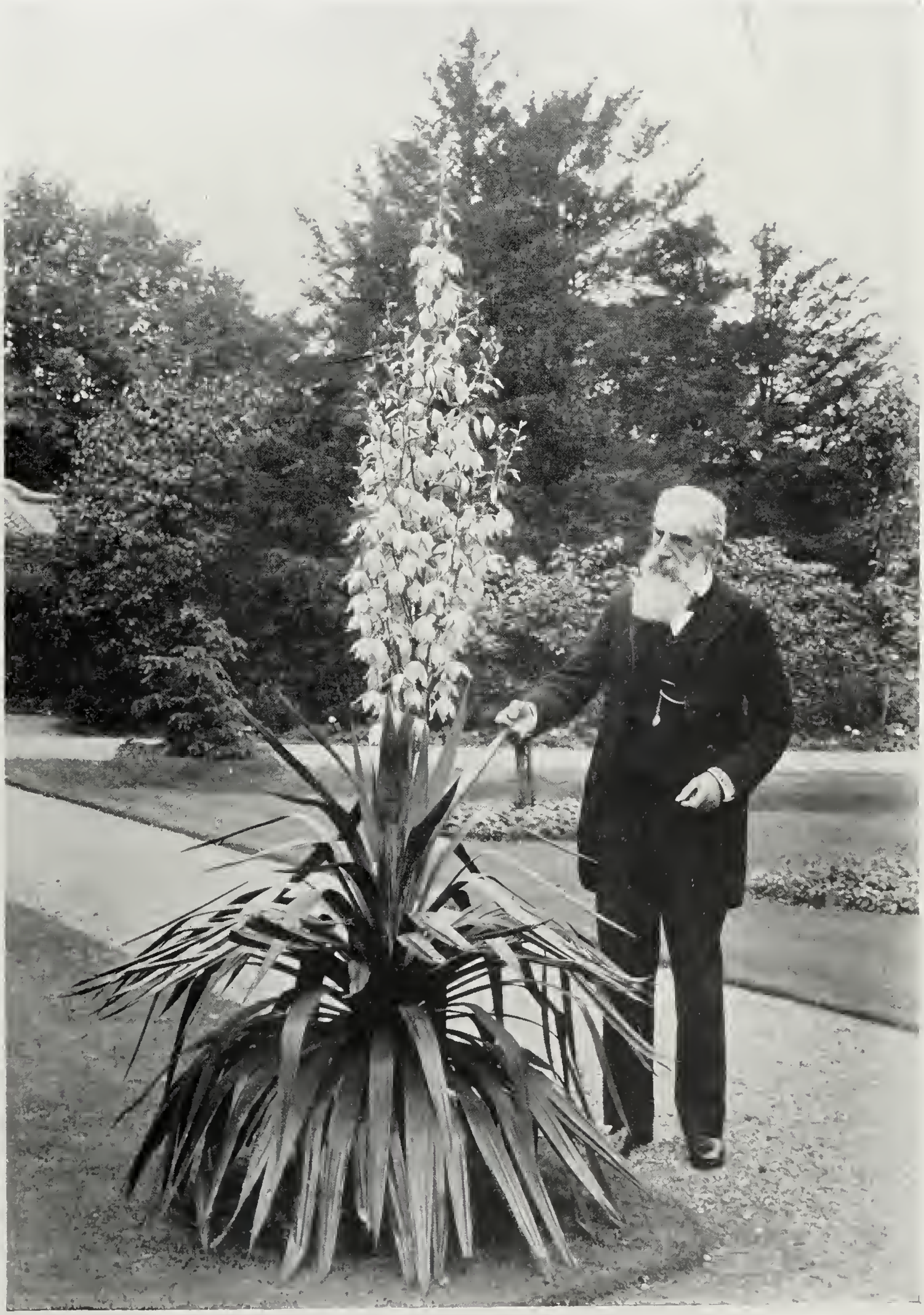

Photo by J. G. Talett, Epsom.

YUCCA PLANT (*Yucca gloriosa*).

The fertilisation of the Yucca—fully described in the chapters devoted to Plant Marriages—is one of the wonders of plant life.

PLATE XXVII.

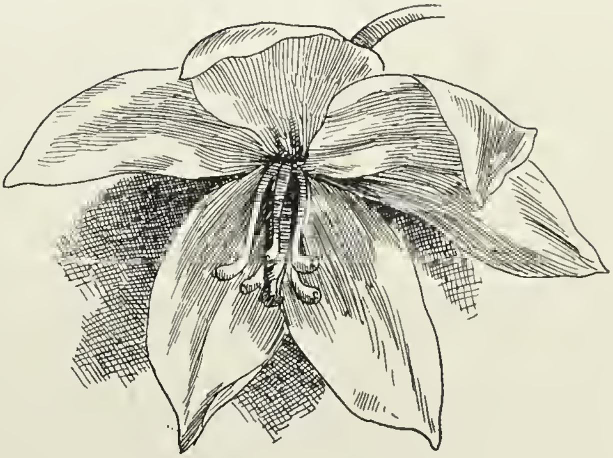

Fig.—537.—*Yucca recurva.*

and thus a supply is ensured for the ovules in each carpel. How perfectly the insect does its work may be gathered from the fact that artificial attempts to cross-fertilise the Yuccas by means of brush-pollination are rarely, if ever, successful.

The larva hatches in about a week, and at first appears to live on the degenerate and swollen ovules; but finally it enters one that is developing. In this state it undergoes three different moults, its colour meanwhile changing from a translucent white to a rosy hue; and with the ripening of the seeds, the larva attains its maturity. Just about the time the fruits are hardening and ready to dehisce, and the seeds are already coloured, the maggot bores a passage through the pod, makes its way to earth (in all probability by the aid of a silken thread), and, tunnelling several inches below the surface, spins in its underground fastness a tough silken cocoon intermixed with the soil. In this condition it remains during the autumn, winter, and spring months, and only transforms to the chrysalis state a few days before the blooming of the Yuccas. The chrysalis is armed with spines on the head and back, by means of which it works its way to the surface, and in due time issues forth a perfect insect; henceforth to live its little life above ground, and, in conjunction with some chosen companion of the other sex, to carry on the useful work which its parents have carried on before it.

Of animals outside the great class *Insectæ* which aid in bringing the reproductive elements of plants together, the chief are snails and birds. Delpino, indeed, divides the plants fertilised by animals into three groups: I. *Ornithophilæ*, or bird-lovers; II. *Entomophilæ*, or insect-lovers; and III. *Malacophilæ*, or snail-lovers. Groups I. and III. remain to be spoken of.

The plants fertilised by the agency of snails are comparatively few in number. The Marsh-calla or Snake-root (*Calla palustris*, figs. 541, 542) may serve as an example; though its chief pollinators are carrion-loving flies, which are attracted to the flowers by their offensive smell. Pond-snails, however, crawl up the partially submerged stem to the spadix, receive pollen from the anthers of the lower ring of flowers, and, continuing their journey, pollinate the female flowers higher up.

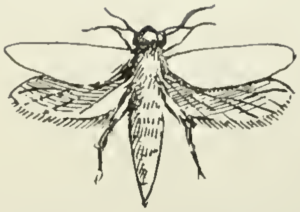
Fig. 538.—*Pronuba Yuccasella.*

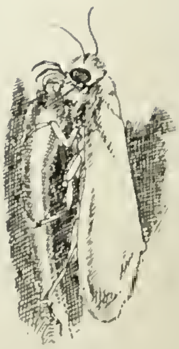
Fig 539. — *Pronuba Yuccasella* gathering pollen.

In *Alocasia odora*, a plant belonging to the same order (*Aroideæ*), snails enter the spathe by a narrow opening, lose their way when inside, and in their purblind efforts to regain the entrance, dust themselves with pollen, which they convey to the stigmas of younger plants. Delpino was of opinion that the snails "are poisoned by an irritant secretion within the chamber of the spathe, and are so prevented from devouring the flowers" after cross-pollination has been effected. The same naturalist has recorded observations on the snail-pollination of *Rhodea japonica* and of *Cypripedium caudatum*, and states of the former that the flowers which proved fertile were always those over which snails had crawled.

Then as to birds. In tropical, and even in temperate America, sun-birds and humming-birds are the welcome guests of many flowers. "Chiefly in the months of July and August," says Waterton, "the tree called Bois Immortel, very common in Demerara, bears abundance of red blossom, which stays on the tree for some weeks; then it is that most of the species of humming-birds are very plentiful. The wild red Sage [? *Salvia coccinea*] is also their favourite shrub, and they buzz like bees round the blossoms of the Wallaba-tree [*Eperua falcata*]. Indeed, there is scarce a flower in the interior, or on the sea coast, but what receives frequent visits from one or other of the species."

It will be noticed that the plants named by Waterton in the above passage all bear *red* flowers; and many naturalists have pointed out that humming-birds appear to have a penchant for scarlet. Fortunately—both for visitors and visited, for bird guests and plant hosts—scarlet blossoms are plentiful in the primeval forests of Central America, where humming-birds chiefly have their home. In those densely vegetated regions may be seen the flaunting reds of the lianes and epiphytes of many widely differing genera, with the dazzling scarlets of Begonias and Fuchsias, of Sages and Lobelias, of Browneas and Erythrinas, the very construction of whose blossoms

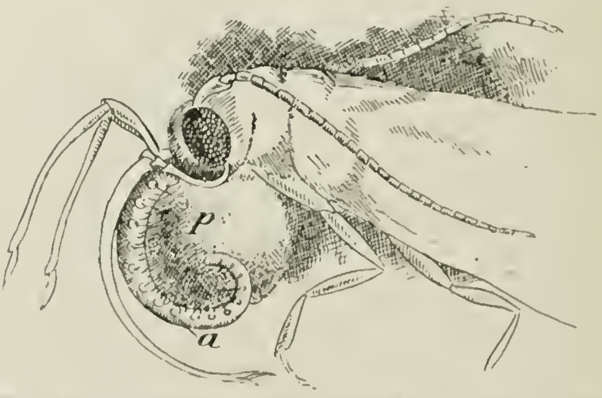

Fig. 540.—*Pronuba Yuccasella* with ball of pollen (*p*) held by tentacle (*a*).

in not a few instances forbids their being rifled by insects. Numbers of such flowers take a lateral direction, and are unprovided with landing-stages; for humming-birds never alight when feeding, but sip the nectar as they hover with widespread wings at the mouths of the flowers (fig. 543). The absence of ridges, knobs, and fringes, which serve so useful a purpose in insect-pollinated flowers, is also to be remarked.

Darwin, in his *Cross and Self-fertilisation of Plants*, gives an interesting summary of the known cases (or such as were known to himself) of bird-pollination, which it will be useful to quote. "In South Brazil," he says, "humming-birds fertilise the various species of *Abutilon*, which are sterile without their aid. Long-beaked humming-birds visit the flowers of *Brugmansia*, whilst some of the short-beaked species often penetrate its large corolla in order to obtain the nectar in an illegitimate manner, in the same way as do bees in all parts of the world. It appears, indeed, that the beaks of humming-birds are specially adapted to the various kinds of flowers which they visit; on the Cordillera they suck the *Salviæ*, and lacerate the flowers of the *Tacsoniæ*; and in Nicaragua Mr. Belt saw them sucking the flowers of *Marcgravia* and *Erythrina*, and thus they carried pollen from flower to flower. In North America they are said to frequent the flowers of *Impatiens*. I may add that I often saw in Chili a Mimus with its head yellow with pollen from, as I believe, a *Cassia*. I have been assured that at the Cape of Good Hope, *Strelitzia* is fertilised by the Nectarinidæ [the Sun-birds]. There can hardly be a doubt that many Australian flowers are fertilised by the many honey-sucking birds of that country. Mr. Wallace remarks that he has 'often observed the beaks and faces of the brush-tongued lories of the Moluccas covered with pollen.' In New Zealand, many specimens of the *Anthornis melanura* had their heads covered with pollen from the flowers of an endemic species of Fuchsia."

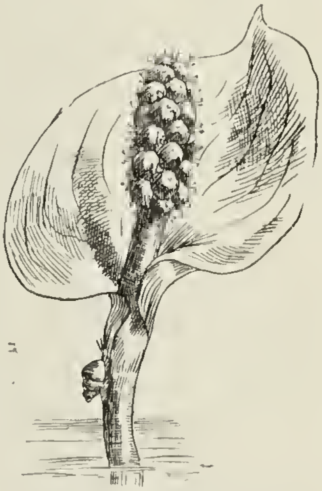

Fig. 541.—Inflorescence of Marsh-calla or Snake-root.

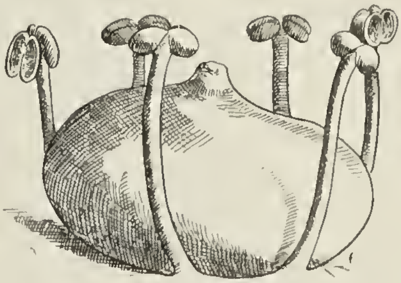

Fig. 542.—A single flower of same.

A later observer, Professor W. Trelease, of the Missouri Botanical Garden, gives a yet longer list, and states that an Alabama planter once laughingly said to him: "You'll have to note every conspicuous flower if you want a full list of those visited by the humming-birds." On several occasions the professor watched the rubythroated humming-bird extracting nectar from the glands at the base of the involucre in cotton-flowers (*Gossypium*); and he found that humming-birds were largely—if not exclusively—used in the crossing of *Malvaviscus*, a scarlet-flowering genus of tropical shrubs.

The observations of a still younger botanist, Mr. William Sugden, of Michigan, are equally worthy of attention. Mr. Sugden tied bags over the flower-buds of *Impatiens fulva*, and also over flowers which had opened, but before the stamens (whose anthers in the first stage form a covering over the pistil) had disappeared. In neither case were good seeds produced, though artificial crossing under similar conditions was successful. Flowers of the same species, unconfined in this manner, but divested of their petals, set no seed whatever; and this was also the result even when the nectar-gland only was removed. Mr. Sugden noticed also that black bees, which visited the free and unmutilated flowers in large numbers, hardly ever touched an anther or pistil, so that they were of no use as pollinating agents. The visits of wild bees and the common honey-bee were equally profitless to the flowers; and even when a humble-bee hit pollen in its plunges to get at the nectar, it left the plant after trying a single flower. With humming-birds the case was quite different. Every time one of these little creatures thrust his arrowy beak into a flower of the first stage, his head would strike the anthers and become dusted with pollen. On visiting a flower in the second stage—*i.e.*, after the withering of the crown of anthers—the bird's head would come in contact with the exposed stigma, with the inevitable result that some of the pollen would be left upon it.

Of the plants which lay themselves out for cross-fertilisation, but which do not invite the co-operation of small animals, some employ water as their agent, and others the wind. External aid for the purpose in question may therefore be of three kinds, and the plants which require those agencies to bring their reproductive elements together may be grouped under one or another of the following heads: *Zoöphilæ*, or animal-lovers; *Hydrophilæ*, or water-lovers; and *Anemophilæ*, or wind-lovers.

Wind- and water-pollinated plants are rigid economists, except in the matter of pollen. They have no attractive odours, no bright petals, no nectar. Birds and insects may be allured by these things, but not so wind and water, which, having no senses to be appealed to, would be unaffected by colour, sweets, or scent. Yet being wasteful carriers, these agents require abundance of pollen; and, if water is to be the vehicle of transmission, the pollen must be either lighter than the water or of like specific gravity; if wind be the agent, the pollen must be smooth, light, and incoherent. In the vast majority of cases these conditions are found to be wonderfully fulfilled.

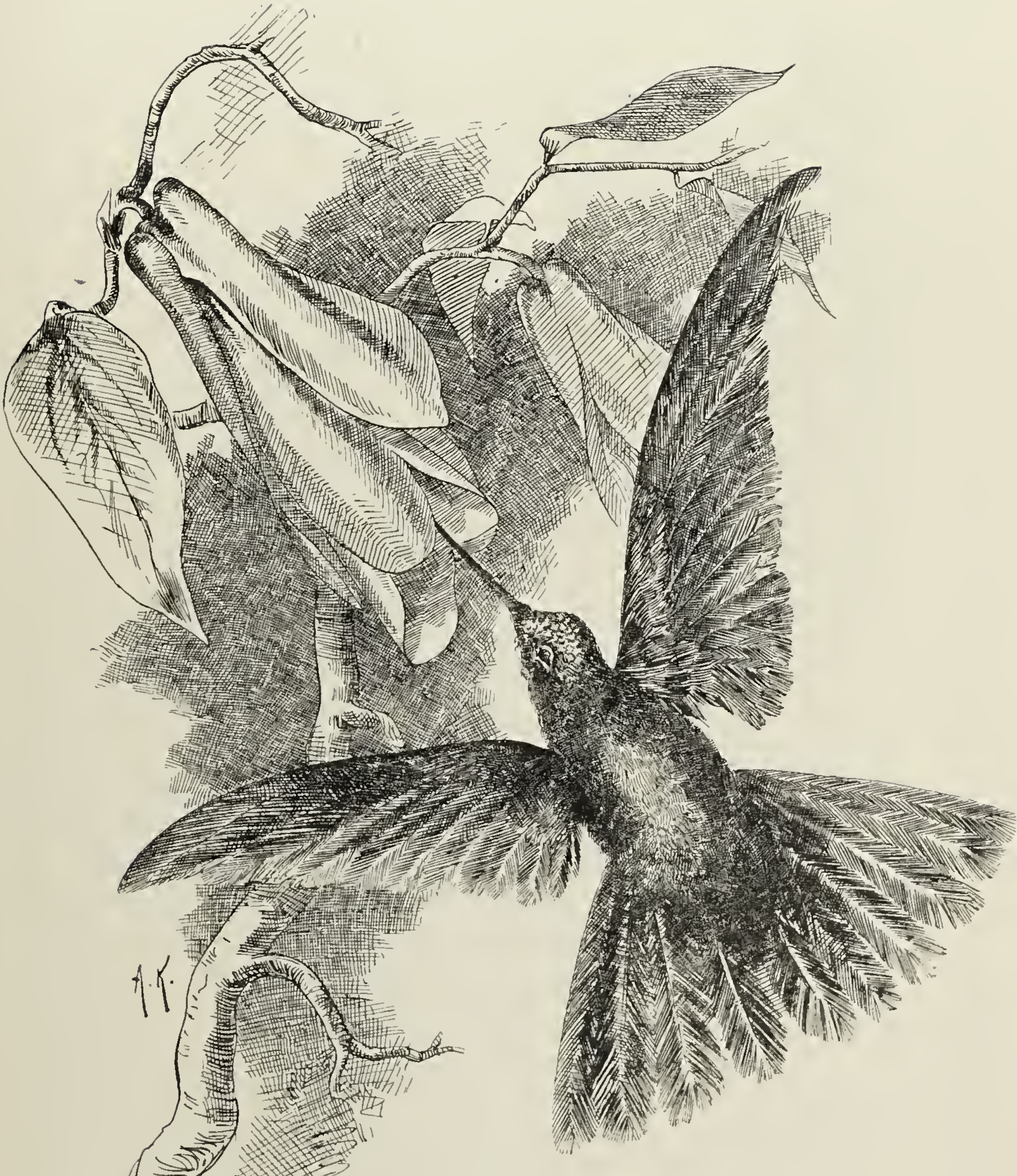

Fig. 543.—A Humming-bird (*Pterophanes Temmincki*) fertilising a Lapageria.

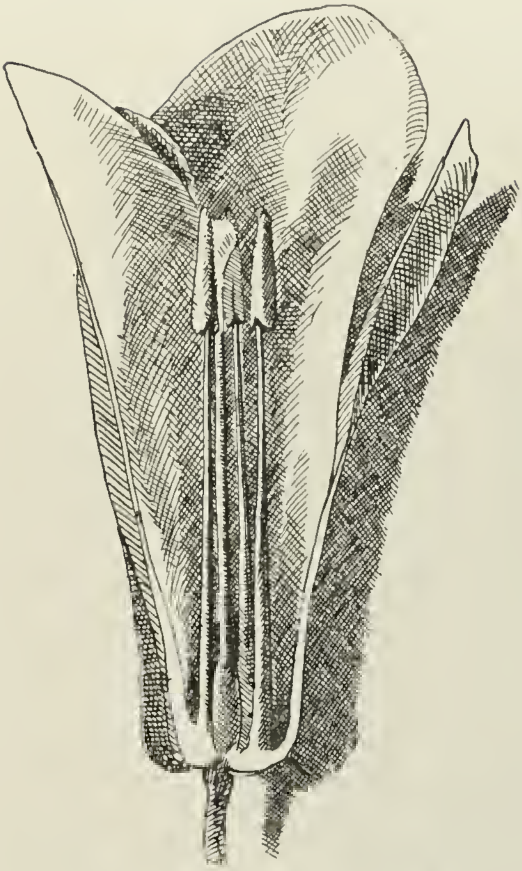

Fig. 544.—Section of flower of Lapageria, with nectary in base of flower.

Of hydrophilous plants some are adapted for fertilisation under the water; and these are provided with a pollen of like specific gravity to the surrounding fluid; others are adapted for fertilisation at the surface, and the pollen of these—unless borne upon a floating raft—is specifically lighter than the water. The Grass-wracks—of which there are but two known species, one of them (*Zostera marina*) British—are remarkable for producing a pollen the grains of which do not, like the generality of pollen-grains, burst in water. Moreover, the grains assume the form of elongated cylindrical tubes on quitting the anthers, which greatly facilitates their conveyance through the water to the thread-like stigmas of the flowers. Something almost analogous takes place in certain cryptogamic plants—notably the *Florideæ* or Red Seaweeds—where the male cells are neither motile nor provided with hairs (cf. pp. 398, 399), but are borne about passively by currents of water till they attach themselves to the slender projecting terminal cells of the female organs.

The Sea Ruppia or Tassel-grass (*R. maritima*), closely allied to *Zostera*, is a British plant adapted for pollination *on the surface* of water. At the period of maturity the submerged flower-stalk lengthens, and the plant lifts its head above the marsh or salt-pool which it inhabits. Lengthening continues until the object is attained, but thereupon ceases, no matter what the depth or shallowness of the water. The Rev. Gerard E. Smith, a botanist well acquainted with the plant, has thus sketched the process: "The anthers are vesicular and buoyant: as they swell and become mature, the membranous sheath enclosing them is distended, and the whole is brought to the surface of the water. The flower-stalks are rapidly lengthened, the flowers quit the sheath, which then becomes a bladder, and aids the elevation of the spike an inch above the water. Presently the anthers burst, the vesicle loses its buoyancy, and the flower-stalks, bearing the fertilised stigma, sink within the bosom of the parent plant." It will be noticed that the flowers both of Tassel-grass and *Zostera* are small and inconspicuous, and possess neither calyx nor corolla. Large blossoms and bright colours would be useless to plants which depend on water for the distribution of their pollen.

Doubtless the most curious of hydrophilous plants is the Italian Eel-grass (*Vallisneria spiralis*), which, indeed, is one of the greatest marvels of the vegetable world. It is distributed throughout Southern Europe, and grows in still water. Our illustration (fig. 545) shows both the male and female plant, with their strap-shaped leaves and flowers in various stages; the male plant is on the right, the female on the left. The pistillate (*i.e.*, female) flowers are borne on long stalks (fig. 546, *a*), each of which, whilst the stigmas are maturing, is enveloped in a kind of bladder. The staminal flowers are similarly invested, but they grow in thick clusters and one sheath suffices for all the individuals of a cluster. Each of these male inflorescences is borne on a short rachis (fig. 546, *b*, *c*), which remains short to the end of the chapter; but at a certain stage the pedicels of the female flowers lengthen to an extraordinary extent, and presently reach the surface of the water. The floral sheaths in the plants of both sexes meanwhile fall apart, and everything betokens readiness for nuptial celebrations.

But now an interesting problem arises. While the female flowers, held by their thread-like pedicels, are floating restfully on the bosom of the water, the male flowers are anchored far down below by their diminutive stalks to the short axes. How are the sexes to be brought together? The problem is solved in a very wonderful, and, at the same time, a very simple manner. The submerged male flower-buds detach themselves spontaneously from their axes, and, being lighter than the water, ascend to the surface. Here they drift about for a while; then open, and, twisting back their three sepals in an ingenious manner, so as to make a float, bring into view the two perfect stamens, which now stand well out of the water like a pair of snail's horns. These miniature floats, as Kerner beautifully remarks, "are blown hither and thither by the wind, and accumulate in the neighbourhood of fixed bodies, especially in their recesses, where they rest like ships in harbour. When the little craft happens to get stranded in the recesses of a female Vallisneria flower, they adhere to the trilobed stigma, and some of the pollen-cells are sure to be left sticking to the fringes on the margins of the stigmatic surfaces." Pollination having been thus effected, the pedicel of the fertilised flower contracts spirally and the ovary descends to the bottom of the water to perfect its seeds.

We come now to the anemophilous or wind-fertilised plants. Most of our native trees, and the grasses, are examples of this group. Wind is far more extensively employed as a pollen-carrier than water, but is not so busy an agent as insects. Flowers which lay themselves out for wind-fertilisation are characterised by abundance of smooth and dusty pollen (cf. pp. 318, 338); by stigmas specially adapted for catching and retaining it; and, as we have seen, by an absence of bright-coloured floral envelopes, perfumes, and honey. "The amount of pollen produced by anemophilous plants," says Darwin, "and the distance to which it is often transported by the wind are both surprisingly great. Mr. Hassal found that the weight of pollen produced by a single plant of the Bulrush (*Typha*) was 144 grains. Bucketfuls of pollen, chiefly of *Coniferæ* and *Gramineæ*, have been swept off the decks of vessels near the North American shore; and Mr. Riley has seen the ground near St. Louis, in Missouri, covered with pollen, as if sprinkled with sulphur; and there was good reason to believe that this had been transported from the pine-forests at least 400 miles to the south. Kerner has seen the snowfields on the higher Alps similarly dusted; and Mr Blackley found numerous pollen-grains, in one instance 1,200, adhering to sticky slides, which were sent up to a height of from 500 to 1,000 feet by means of a kite, and then uncovered by a special mechanism." A shower of pollen which fell in Inverness-shire in the year 1858 (our authority is Professor Ainsworth Davis) covered the ground to a depth of half an inch.

Of the three great classes into which the Flowering Plants are divided—namely, Monocotyledons, Dicotyledons, and Gymnosperms—one class, the last named, is entirely composed of wind-fertilised plants. The Gymnosperms derive their name from the fact that their ovules are not contained in an ovary—they are naked. The flowers, which are unisexual and without calyx or corolla, would stand but a poor chance of perfecting their seeds were it not for the kindly offices of the wind.

The Scots Pine (*Pinus sylvestris*) offers a good example of the wind-pollinated gymnosperm. Its inflorescences are cones, the male cones which grow in clusters, being much smaller than the female. In the month of June the anthers open, and discharge their *winged* pollen, which is furnished with microscopic air-bladders (fig. 501), into the grooved backs of the membranous anther-scales, where it lies ready for the breeze to scatter it. Meanwhile the female cones get ready for the "sulphur shower," and being unprovided with any stigma or subsidiary stigmatic appendage, the naked ovules exude a viscid substance which holds fast the pollen that falls in their way, and which, as it dries up, draws the pollen through the micropyle into the interior of the ovule. The fertilised ovules do not arrive at maturity—that is, become ripe seeds—for two years; and hence every female cone may be said to have three periods, which correspond with three distinct stages in the development of the inflorescence. In the first period the cone is green and small, and is seated on one of the very young shoots; in the second period (*i.e.*, at the beginning of the second year) the cone is larger, but still green, and of course the shoot has become older; in the third

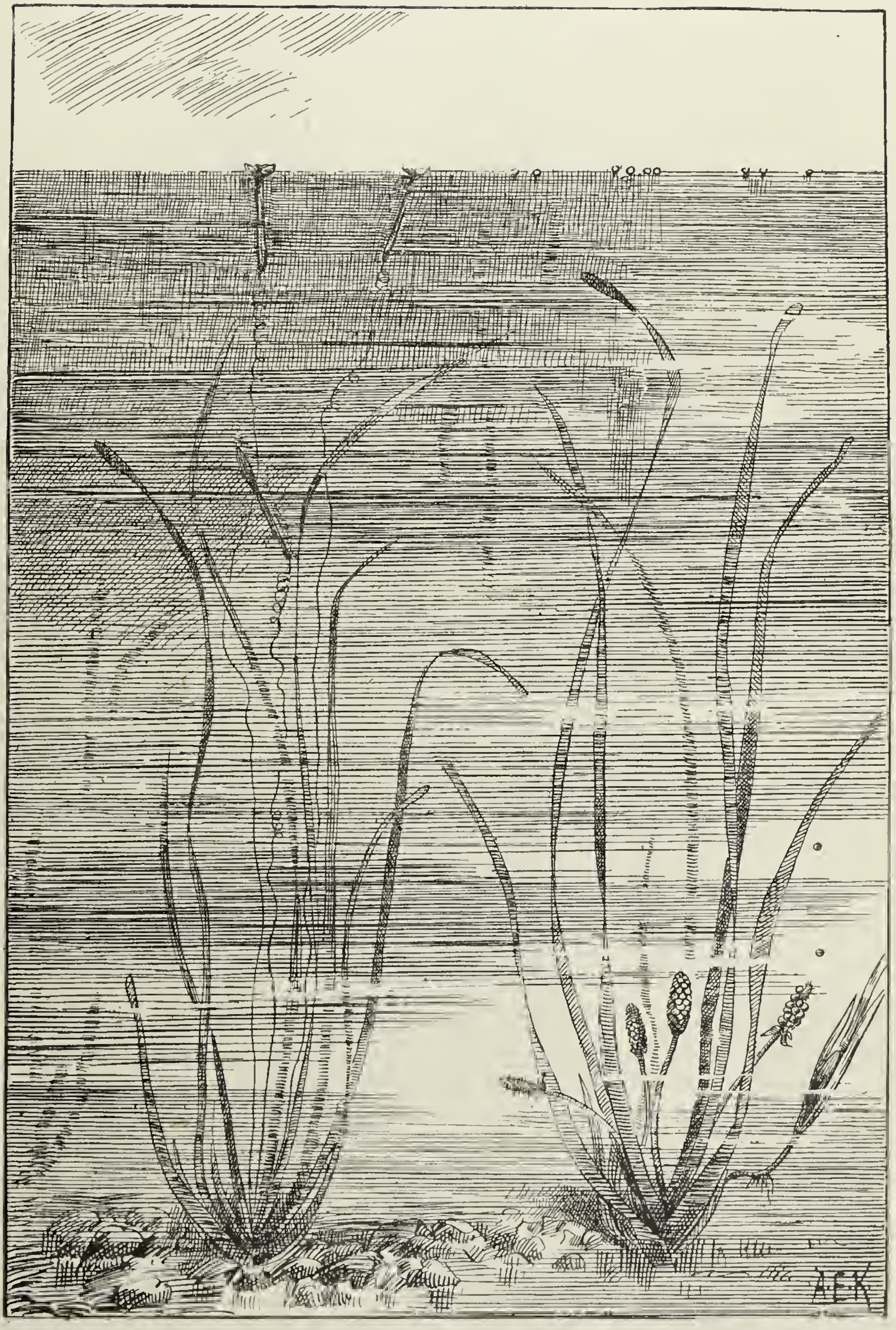

Fig 545.—*Vallisneria spiralis* (male plant to the right).

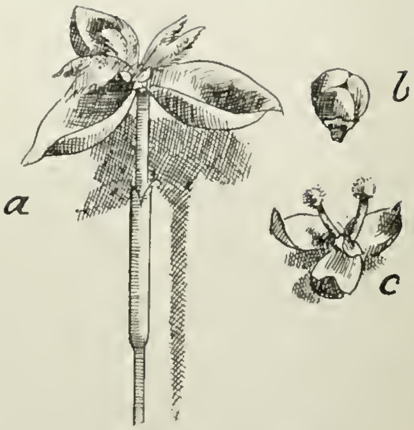

Fig. 546.—*Vallisneria spiralis.* (*a*) Female flower. (*b*) Male flower unopened. (*c*) Expanded male flower.

period—the cone being now two years older—the scales have become brown and woody, and the seeds are ripe.

Among the Angiosperms (Dicotyledons and Monocotyledons) the contrivances for wind-pollination are more elaborate than among the Gymnosperms. "The anemophilous angiosperms," says Hermann Müller, "have for the most part enormously developed stigmas, which project in the form of long tails, brushes, laminæ, or discs; their male flowers are very seldom immovable, but are generally easily shaken by the wind, either the axis of the male inflorescence or the peduncle of the male flowers, or the filaments themselves, being long and pendulous; in some cases the stamens are explosive, and project all the pollen into the air."

We may take as our first example the flowers of the Hazel (*Corylus Avellana*). Most people are familiar with the long pendulous "lambs' tails," as the children call them, which make their appearance on the Hazel in the autumn, and which, in the South of England, open in January or February. These are the male inflorescences or catkins * (fig. 548). The female inflorescences are the small cone-like growths (*strobiles*), sometimes rather loosely described as "female catkins," which appear in the axils of the new shoots. The tiny groups of crimson threads projecting from the tops of the strobiles are bunches of forked stigmas. The anthers open while the hazels are still bare of leaf, and roll out their pollen into the trough-like depressions of the flower's scaly bracts, which retain it "until the tassels are set swinging by a gust of wind." Then the yellow dust, with no foliage to impede it, is blown hither and thither, and the stigmas of a great number of female flowers are sure to get pollinated.

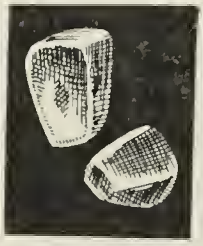

Fig. 547.—Pollen-grains of Great Panicled Sedge (*Carex paniculata*).

That *pendulous flowers*, no less than pendulous inflorescences, should facilitate the scattering of pollen by the wind goes without the saying. Many species of *Rumex*, the genus to which our Broad-leaved Dock and Sheep's-sorrel (*R. obtusifolius* and *Acetosella*) belong, are of this kind, and are anemophilous. In the Alpine Dock (*R. alpinus*) and Garden Sorrel (*R. scutatus*), the anthers are pendulous at the ends of the delicate filaments, and the pollen-dust is shaken out of them in the lightest breeze.

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* The more technical name for a catkin is an *amentum*.

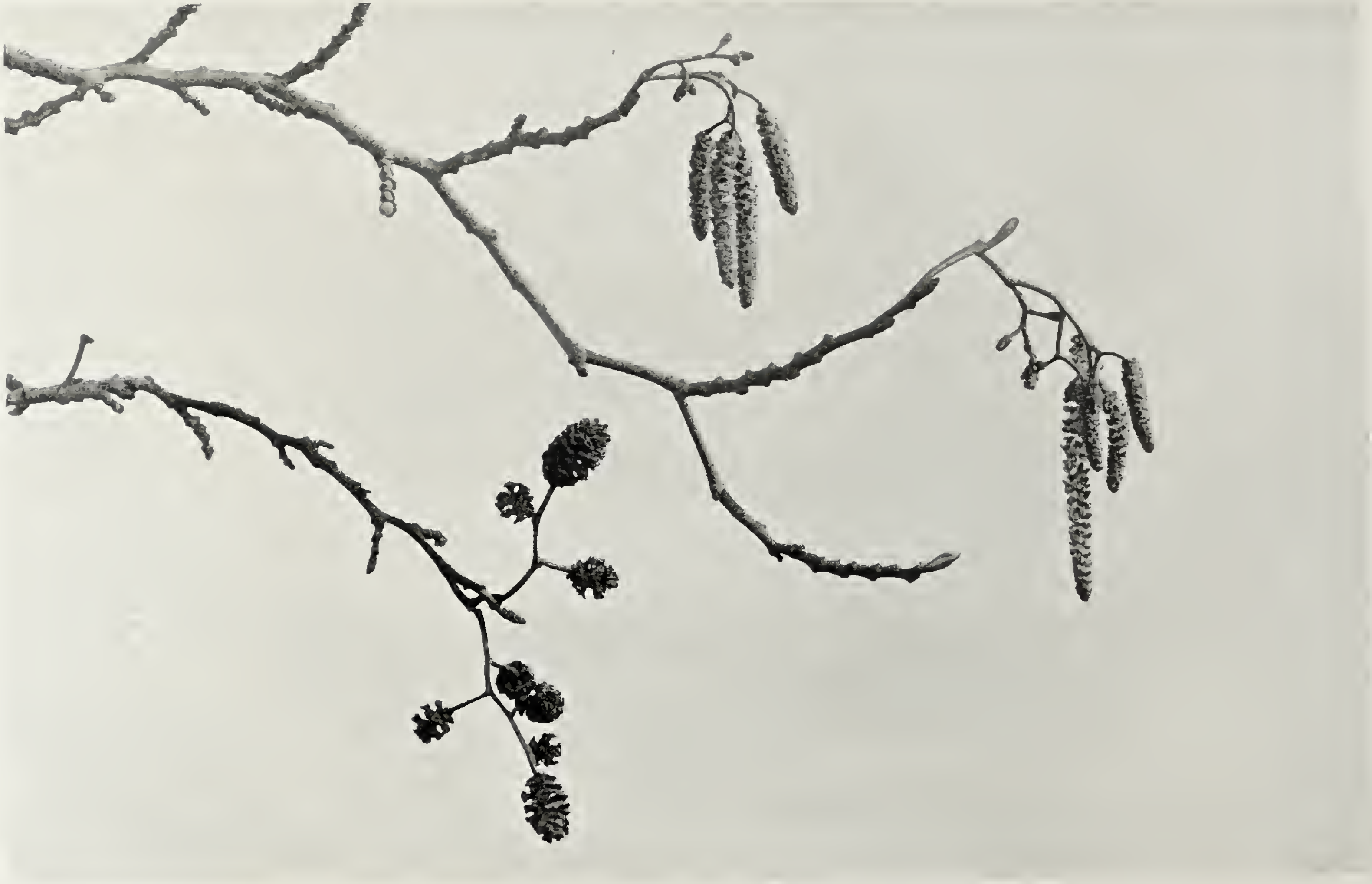

Photo by Henry Irving.

Male and Female Catkins of the Alder (*Alnus glutinosa*).

Plate XVI.

Most of the Sorrels, however, and with them the Grasses, Sedges, Rushes, and Wild Plantains, are embraced under a far more common variety of anemophilous flowers—namely, *the forms with long stamens.* In the Rye-plant (*Secale cereale*), for instance, the essential organs protrude freely from the widely expanded flowers, and cross-pollination is effected on a large scale by the wind. Delpino has some interesting observations on the Ribwort Plantain (*Plantago lanceolata*) which seem to show that the flowers of this species are in process of development from an anemophilous to an entomophilous form. He says: "One form, with a strong and very tall scape, and very broad white anthers which quiver in the wind, grows in meadows and is exclusively anemophilous, for I have never seen it visited by insects. The second form grows on the hills, and has a much shorter scape; it also is essentially anemophilous. I once saw a species of *Halictus* on a spike, trying to get pollen; but the structure of the flower is so unfitted for pollen-collecting, that great part of the pollen fell to the ground without benefiting either the plant or the insect. Finally, the third form is dwarfish and confined to the mountains; it has the shortest spike and filaments; on meadows in the Apennines at Chiavari I have seen bees in numbers flying from one flower to another of this variety, collecting the pollen and performing cross-fertilisation.

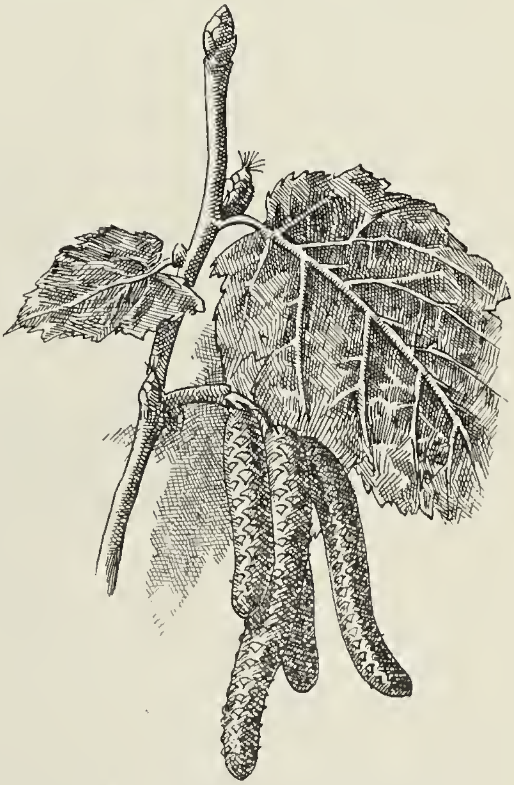

Fig. 548.—Catkins and strobiles of Hazel.

"This, therefore, is a form of *Plantago* which hangs between the anemophilous and entomophilous conditions, and is capable of being fertilised equally well by the wind and by the bees. If the filaments became stiff and coloured, and the pollen-grains adhesive, while the anthers lost their peculiar quivering, we should have before us the passage from anemophilous characters, the evolution of an entomophilous from an anemophilous species.

"This hypothetical transition has actually occurred. *Plantago media* is a form that has become entomophilous; the filaments have become pink, the anthers are motionless, the pollen-grains have become more aggregated, and it is visited regularly by *Bombus terrestris*, as I have observed at the same spot (Chiavari) in the Apennines."

Explosive forms of anemophilous flowers are met with in the Nettle family (*Urticaceæ*) and a few other species. The Great Nettle (*U. dioica*, fig. 550) is an excellent example. Here the sexes are on different plants, and the flowers are small, green, and inconspicuous. While the male flower is unopened, the stamens, which are furnished with an elastic tissue, curve inwards; but as the flower matures, they gradually become dry, and, as a result of this dryness, spring outwards, spurting the pollen into the air. In this way they assist the wind in disseminating the fecundating dust.

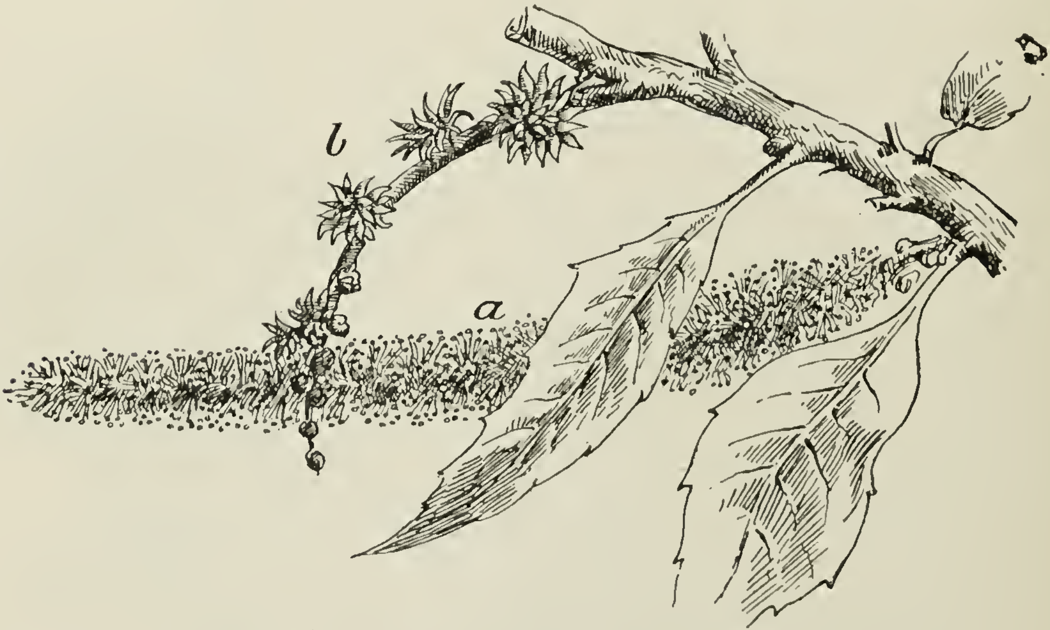

Fig. 549.—Catkins of Sweet Chestnut (*Castanea sativa*). (*a*) Male. (*b*) Female.

The Wall-pellitory (*Parietaria officinalis*), a common weed on old walls and in dry waste places, scatters its pollen in a similar manner. The coiled-up stamens are highly irritable, and at the proper time force asunder the segments of the calyx which hold them down and flirt out their pollen. It is a remarkable fact that, in the hermaphrodite flowers of this plant, the brush-shaped stigma of the pistil falls off before the anthers dehisce, and thus self-pollination is prevented.

Closely related to the Nettles and Wall-pellitory is the equally remarkable Artillery-plant (*Pilea microphylla*). This is a small plant, with leaves resembling those of Wild Thyme, and minute diœcious flowers, common enough in indoor ferneries. The English name refers to the copious discharge of pollen when the stamens straighten themselves—a phenomenon which may be artificially induced by sprinkling the plant with water. The anthers empty themselves instantaneously, the contents flying out like the puff of smoke from a distant gun.

The only other group of wind-pollinated plants which need be noticed here is that which comprises the *forms with immovable flowers.* In these it is usual to find that provision is made for temporary storage of the pollen *should no wind be stirring when the anthers dehisce.* For instance, in the Arrow-grass (*Triglochin palustre*) the pollen is rolled into the deep concavities of the perianth leaves; while in the Sea-buckthorn (*Hippophaë rhamnoides*) it is discharged into little bladders formed by the uniting concave scales in which the stamens lie. Let a warm dry wind spring up, and the bladders open by narrow chinks, and set free the pollen—which, however, can only escape a little at a time. The Broad-leaved Pond-weed (*Potamogeton natans*) is a good example of a wind-pollinated plant with immovable flowers.

Here our chapter must close, though not for lack of matter to carry us farther. The subject of the Pollination of Plants is inexhaustible, and must ever remain so; for, in pursuit of the study, we are brought again and again—as in the study of the *Life* of Plants—to the borders of the Unknown Land. Here it is that questions press upon us which, as Schleiden finely remarks, we can neither repel nor answer. "What has the wind to do with the date-harvest of Bileduljerid, and with the sustenance of millions of men? What cares the gall-fly that on its activity depends the fig trade of Smyrna, and the food or support of thousands of human beings? Or does the beetle, whose theft facilitates the increase of the Kamschatkan Lily, imagine that their bulbs shall be the means to save the whole population of Greenland from starvation in the following hard winter? If all this is the result of unsubstantial natural laws, whence this wonderful interdependence and connection of subordinate forces, to bring to pass events which have so deep an influence on the history of humanity? We do, indeed, see into the mechanism of the puppet; but who holds the strings, and directs all its motions to *one purpose*? Here closes the office of the naturalist, and, instead of answering, he turns from the world of space and lifeless matter upward to where, in holy anticipation, we seek the Ruler of Worlds."

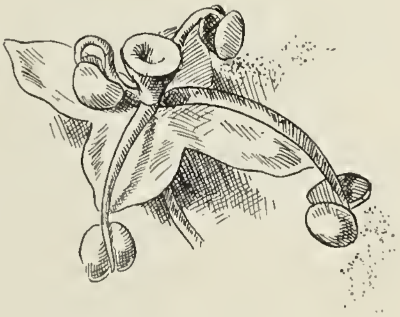
Fig. 550.—Staminate flower of Stinging Nettle.

CHAPTER XIII

THE PROMISE OF THE PLANT THAT IS TO BE

> . . . Fruit and seed,
> New loosed from thorn-bush, tree, and flaunting weed,
> And now by wing, or scale, or plume up-borne,
> Fare forth on pilgrimage.

WHEN water, wind, or animal (or, it may be, the unaided plant) has fulfilled its function as an agent of pollination, the true process of *fertilisation* begins. The outcome of fertilisation is the *fruit.*

In popular language the term "fruit" may mean many things, but botanists usually confine it to the ripened pistil or ovary of a flower. Possibly this use of the term is rather too exclusive. Kerner would extend the definition to "everything which undergoes alteration after fertilisation either in the flowers or flowering axis," and urges that as the changes in question are "for the purpose of promoting the interests of the embryo," whatever participates in this object is the fruit. However, not to appear singular, we will abide by the definitions of the text-books, and take it that a fruit is a ripened and developed ovary.

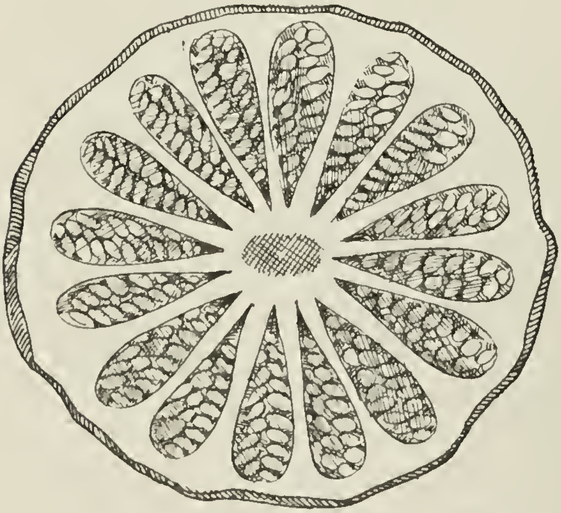
Fig 551.—Transverse section of ovary of White Water-lily.

How does this ripening and development take place? The accompanying figures will help us to understand the process. Fig. 552 represents an ideal section through a uniovular ovary just after pollination. *a* is the stigma, upon which are six pollen-grains. The style (*b*) widens into the ovary (*c c*), which contains a single *inverted* ovule (*d*)—the latter not shown in section. We speak of the ovule as inverted because the micropyle (*g*) (cf. Chap. VI., p. 116) is not at the apex of the ovule, but, by a twisting round of the whole ovule, is brought close to the *funicle* or point of attachment (*f*).*

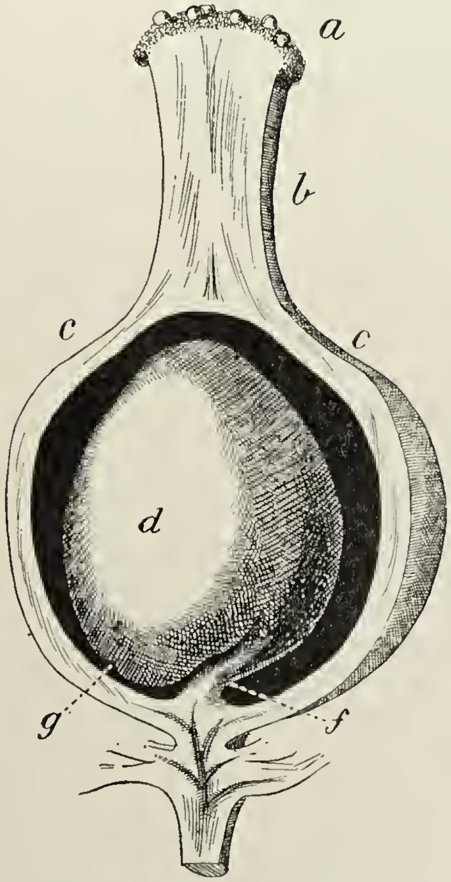

Fig. 552.—Ideal section through a uniovular ovary just before fertilisation (the ovule is not in section). (*a*) Stigma, upon which are six pollen-grains. (*b*) Style. (*c c*) Ovary containing a single inverted ovule (*d*). (*f*) Stalk (funicle of ovule). (*g*) Aperture (micropyle) of ovule through which the pollen-tube enters on its way to the embryo sac.

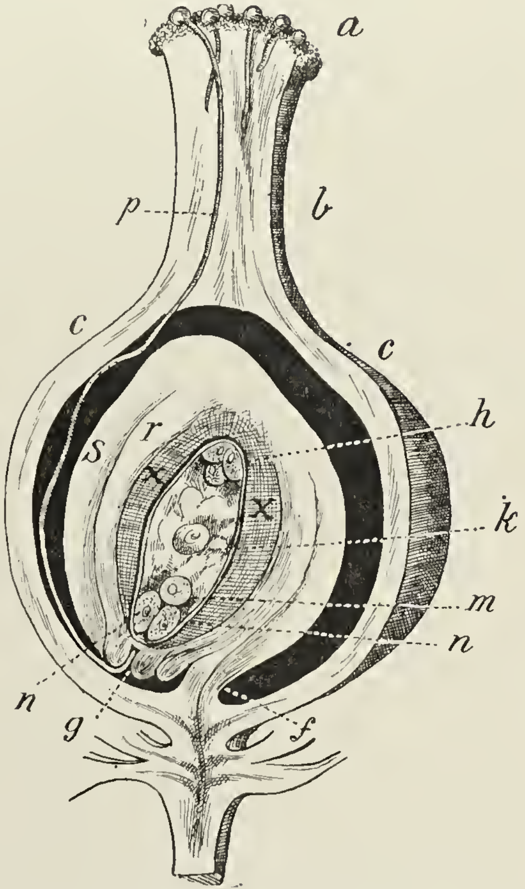

Fig. 553.—The same, showing the ovule in section. (*h*) Antipodal cells. (*k*) Central nucleus. (*m*) Egg cell (oosphere) from which, after fertilisation, the embryo plant is developed. (*n n*) Co-operating cells (synergidæ). [The space which contains the above-named cells (*h*, *k*, *m*, *n*), and which is shown in the drawing surrounded by a double line, is the embryo sac. The shaded part surrounding it is the nucellus (*x*).] (*p*) Pollen-tube entering the micropyle. (*r*) Inner envelope (integument) of ovule. (*s*) Outer envelope (integument) of ovule.

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* This is the commonest form of ovule, and is described as *anatropous*. It must be carefully distinguished from the bent or *campylotropous* form, in which the ovule curves upon itself like a horseshoe, and so brings the micropyle near the base. This is well seen in the Pea (fig. 554) and in the seeds of Shepherd's Purse (*Capsella Bursa-Pastoris*). Straight or *orthotropous* ovules, which have the funicle and nucellus in the same straight line, are common among the Gymnosperms, and occur also in the Dock family. The Yew (*Taxus baccata*), a female flower of which is figured on p. 375, offers an excellent example of this form.

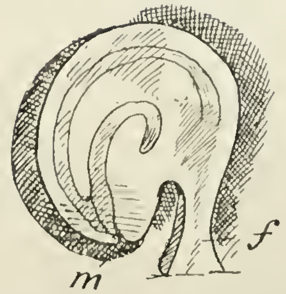

Fig. 554.—Campylotropous ovule of Pea. (*m*) Micropyle. (*f*) Funicle.

Fig. 553 shows the same pistil, but with the ovule also in section. Observe the structure of the ovule, here represented at the stage immediately preceding fertilisation. Commencing from the outside, we have first a coat or envelope (*s*)—the *outer integument*; secondly, an inner coat (*r*)—the *inner integument*; and within that a mass of tissue (*x*), represented by the cross-hatched shading—the *nucellus*. Embedded in the nucellus is the *embryo sac*, which contains an abundance of protoplasm, with large vacuoles and a central nucleus (*k*); and in addition to the protoplasm, a number of small cells (*m*, *n*, etc.) First and chief is the egg-cell or *oosphere** (*m*), from which, after fertilisation, the embryo plant is developed. Its two sister-cells (*n n*), which co-operate in this work, are known as the *synergidæ*. They are situated somewhat nearer the micropyle (*g*) than the oosphere, and constitute with it the "egg apparatus." The three cells at the opposite end of the embryo sac are the *antipodal* cells. Soon after their formation each of the antipodal cells becomes invested with a cell-wall, but they appear to play no part in subsequent phenomena, and their use is not at present known.

Watch the process of fertilisation. On putting forth its tube the pollen-grain shapes a course down the loose conducting tissue of the style until it reaches the micropyle of the ovule. The tube, it should be explained, is an outgrowth of the inner coat or *intine* of the pollen-grain through the *extine* or outer coat (fig. 555), and it bears at the end a reproductive nucleus, which is in fact the male sexual cell or *male gamete*. Forcing its way down the micropyle, the pollen-tube perforates the embryo sac, and then, opening at the tip, allows the reproductive element—which has meanwhile divided to form two male cells—to pass out. Thus released, the generative nuclei traverse the synergidæ—which thereupon shrivel and collapse—and, with that, one of these male cells enters the egg-cell and fuses with the female nucleus. *This is the act of fertilisation.*

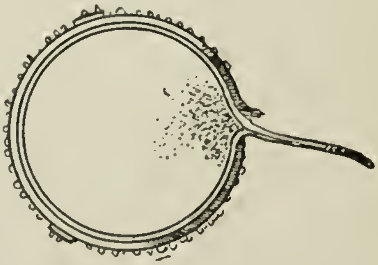

Fig. 555.—Intine growing out of a pollen-grain through the extine.

The cell formed by the fusion of the male and female nuclei is called the *oosperm* or embryonic cell; and from this cell (as the latter name suggests) is eventually formed the embryo or baby plant—the essential part of the *seed*.

Immediately after fertilisation *endosperm* begins to form in the embryo sac, either by

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* Called also the *germsphere* and *ovum*.

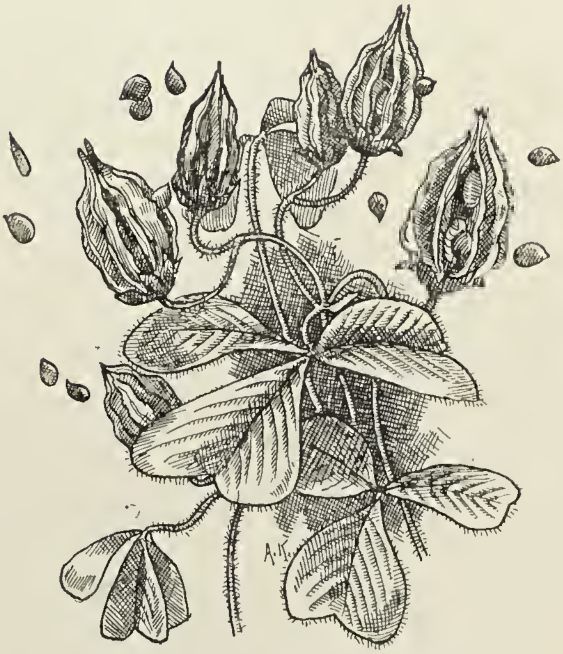


Fig. 556.—*Oxalis* expelling its seeds.

cell division—as in some Dicotyledons—or by free cell formation—as in all Monocotyledons and many Dicotyledons. The embryo sac meanwhile increases greatly in size and gradually absorbs the tissue of the nucellus. In plants of the Water-lily and Pepper orders (Nymphæaceæ and Piperaceæ) and a few others, a portion of the nucellus remains, and forms what is known as *perisperm.* When both the endosperm and perisperm are completely used up by the embryo in the course of its development, the ripe seed consists simply of a seed-coat (formed from the integuments of the ovule) and the embryo, and is called *ex-albuminous.* In cases where the ripe seed contains endosperm as well as the embryo, it is called *albuminous.* As we have already dealt with the subject in Chapter VI., we need not retrace the ground here.

From what has been said, however, the distinction between a fruit and a seed must be at once evident. The former is a ripened and developed *ovary*; the latter, an impregnated and matured *ovule.* The fruit, in fact, *contains* the seed, just as the ovary contains the ovule. (Of course an ovary may contain many ovules, and a fruit may contain many seeds.) In the Gymnosperms, which have naked ovules, the seeds are of necessity naked also; hence they are not true fruits. True fruits are, indeed, confined to the Monocotyledons and Dicotyledons.

In dealing with the diversities of form and external structure of fruits and seeds, it is interesting to consider them in the light of Adaptation. By this means the inquiry is immensely simplified; for it is evident that those diversities are mainly directed to one end—*the dispersion of the seed.* The seed, in fact, must be adapted to travel.

Now seeds and fruits were great travellers centuries before Vasco de Gama and Columbus were heard of, and had crossed seas and continents, and planted colonies all over the world long before the earliest caravan set out from Bactria, or the first Phœnician merchantmen spread sail on the blue waters of the Mediterranean. The necessity for becoming travellers was imposed upon the vegetable community from the outset. Had those old-world fruits just fallen from their parents' arms, so to speak, and lain where they dropped, the consequences must have been disastrous. In a few years vegetation would have been almost choked; the strongest plants would have killed out the weaker, whole familes of plants would have thus become extinct, and the distribution of the remainder would have been much retarded.

It is therefore a matter for thankfulness that Nature has made abundant provision for the dispersal of the fruits and seeds of plants. This great end is effected in many ways. Sometimes the plant ejects its own offspring in a more or less forcible manner by means of special tissues which act as slings, catapults, etc.; sometimes the fruits themselves are capable of creeping or hopping along the ground; sometimes they are provided with plumes or with envelopes filled with air, which render them so buoyant that they are able to perform long aerial journeys, the least breeze being sufficient to carry them along; sometimes the wind lays hold of them when on the ground and drives them forward with rapidity; sometimes the water is their friend, and stream and torrent, lake and ocean, become instrumental in transporting them to new and distant homes; sometimes the fruits are furnished with hooks or sticky secretions which facilitate their dispersion by birds and other animals.

The English Wood-sorrel (*Oxalis Acetosella*), whose delicate white blossoms may be often seen peeping among the mossy uncovered roots of forest-trees, is one of our commonest wild-flowers. It offers a familiar example of plants with sling fruits. When the seeds are ready for dispersion, the capsules containing them burst open, and the strong tense tissue which covers each of the seeds being ruptured at the same time, the seed is jerked out to a considerable distance. In the Squirting Cucumber (*Ecballium Elaterium*, fig. 558) the arrangement is even more curious. The seeds are contained in a juicy pulp, which fills the fleshy and bristly "cucumber," and which is kept from bursting out by the hooked and stopper-like stalk. When the seeds are ripe, the fruit severs itself from the stalk, and instantly the seeds are squirted out in a fountain of pulp through the unprotected hole. In the Touch-me-not Balsam (*Impatiens Noli-me-tangere*, fig. 559) the five divisions of the capsule leap from the stalk when the seeds are ripe, and, twisting suddenly up, get rid of their offspring in a very summary manner —not with unkindly intentions, we may be sure, though Erasmus Darwin gives *Impatiens* a very bad character in his *Loves of the Plants*:—

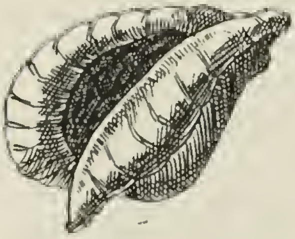


Fig. 557.—Seed of Common Wood-sorrel. The elastic outer integument is bursting open to expel the seed.

With fierce distractful eye *Impatiens* stands;
Swells her pale cheeks and brandishes her hands:
With rage and hate the astonished grove alarms,
And hurls her infants from her frantic arms.

The Common Dandelion (*Taraxacum officinale*, fig. 560) offers the most familiar example of the dispersal of plumed fruits by means of the wind. Each of its white downy balls, "the schoolboy's clock in every town," is an aggregation of such fruits, waiting for the first breeze to scatter them. The beauty of these tiny parachutes, and the gracefulness of their motion as they float through the summer air, cannot be too greatly admired. The Tillandsias, many of which are epiphytes, have plumed fruits which are specially adapted for anchoring them to the bark of old trees, where they are able to germinate immediately. In *Cirsium nemorale*, one of the Plume Thistles, the fruits just break away from their sessile plumes and fall to the ground, whenever an obstacle is encountered in the course of flight. Doubtless the obstacle gives sufficient promise of *terra firma* below to encourage them thus to slip their parachutes and risk a descent.

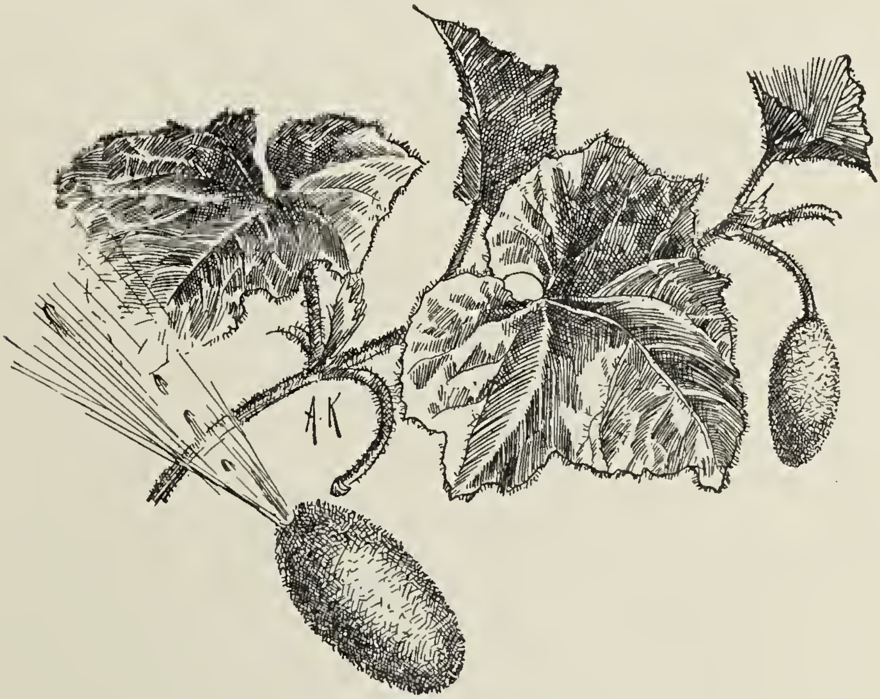


Fig. 558.—Squirting Cucumber.

Creeping fruits are characterised by their stiff bristles, which are peculiarly sensitive to moisture. As a result of this sensitiveness, the fruits continually change their position, and are able to propel themselves along in a definite direction, a hygroscopic arrangement which enables them to be carried long distances.

Even jumping fruits are not unknown. Insect activity within the fruit is the cause of the phenomenon, and one of its effects is undoubtedly the dispersion of the seeds. Mr. G. Nicholson, F.L.S., informs the writer that two plants are known which have so-called "jumping beans"—viz.,

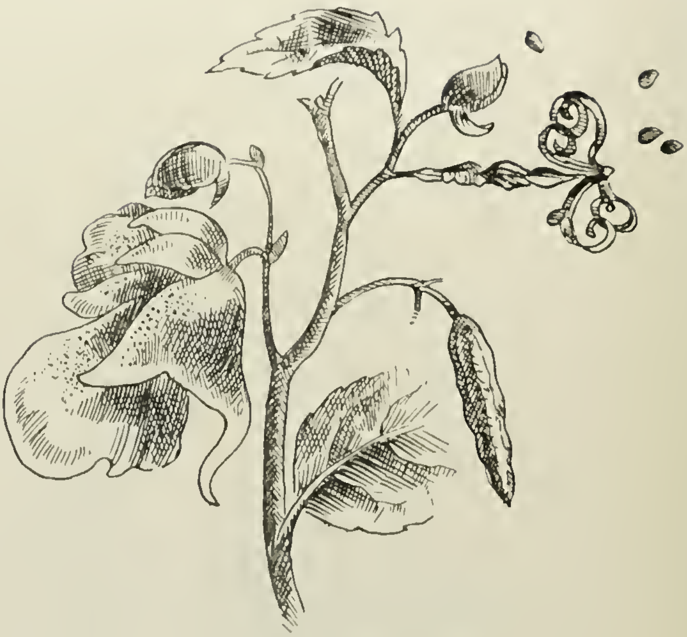


Fig. 559.—Touch-me-not Balsam expelling its seed.

Sebastiania Palmeri and *S. bilocularis*; and that the insects which cause the motion are *Carpocapsa saltitans* in the former, and *Grapholitha Sebastiania* in the latter. *Sebastiania Palmeri* is a very peculiar tree. It was discovered not long since in a morass, half a mile square, in the neighbourhood of Alamos, Mexico. The fruit is of triangular shape, divided into three equal portions by strongly defined lines (fig. 702). Two of these parts contain a small spherical black seed; the third, a "jumper" or small maggot, with sixteen feet, which measure about eleven millimetres in length and three in width (*c* and *d*). On falling to the ground the fruits split, and that portion which contains the maggot immediately starts off, jumping in an extraordinary manner *away from the tree on which it grew* (*b*).

The object of these movements has not yet been discovered, but the theory is that the maggot instinctively knows that if it remains near the parent tree it will be destroyed by an enemy. The insect lives upon the contained seed, and has no desire to escape—indeed, seems to be extremely comfortable in its dark quarters. If a small hole is carefully bored in the shell, the maggot instantly sets to work to repair the damage, and in a very short time will have closed the hole with a fine silky web. After this is done the insect resumes its tireless and saltatory travels. As there is no hole or other indication of a way by which the shell could be entered, it is supposed that the egg is laid in the flower before the fruit is formed; probably also, the moth which lays the egg cross-pollinates the flower at the same time. Our drawing of the perfect insect (*f*) was made from a live specimen obtained from one of the nuts in this country by a friend of the writer. It is a grey-brown moth, with speckled upper wings which measure three-quarters of an inch from tip to tip. The moth released itself from its prison by chiselling out a piece of the hard shell, like a circular pavement-trap in miniature. The most delicate fret-saw, even in skilled hands, could not have done the work better. It must be understood that these "jumping beans" never produce seedlings, for the contained larva destroys the seed.

Instances are even known of *whole plants* which migrate from place to place when their fruits are ripe. Of this sort are the wonderful "wind-witches" of the Russian steppes, which have so appealed to the imagination of the peasants of those regions. At the fruiting stage the stiff erect flowering stems of this plant, which spring from a common axis almost level with the root, curve outwards to the circumference of the plants, and by that means give a strong pull to the radish-shaped root, sufficient to force it from the ground. The environment of the plant favours this singular and apparently suicidal proceeding, for the earth during the summer season is full of cracks. Then, when the wind comes howling over the steppes, the plant is caught up and driven along with others of its kind, and together they fly bounding over the plain. One by one their wild careers are checked, and each settles down to shed its seeds in its new resting-place.

Having offered these general remarks, we will now consider the subject of the Phanerogamic Fruit in more detail.

A fruit or ripened ovary consists, normally speaking, of two parts—the protective enveloping case, known as the *pericarp*, and the seed or seeds (ripened ovules). The pericarp consists of three layers, each of which has a distinguishing name. The outermost layer—*i.e.*, the integument or skin of the fruit—is the *epicarp*; the middle layer is the *mesocarp*; and the inner coat the *endocarp*. When, as frequently happens, the middle layer is of a fleshy or succulent nature, it is called the *sarcocarp*.

It was noticed a few pages back that parts of plants are sometimes described as fruits which are not true fruits at all. We call these spurious fruits *pseudocarps*. The strawberry, apple, fig, and mulberry are familiar examples. The red, succulent, fleshy

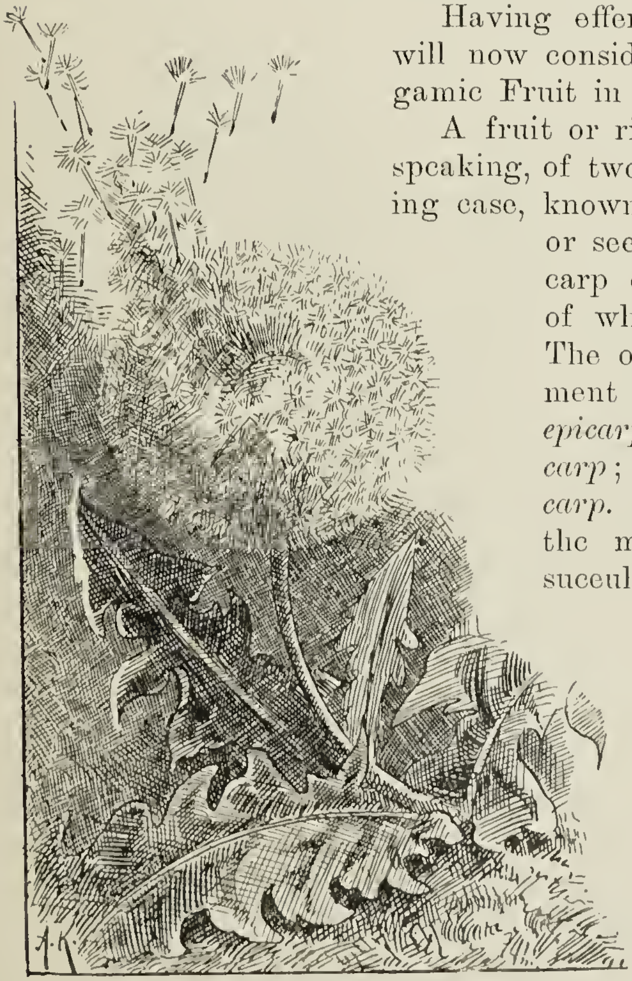


Fig. 560.—Plumed fruit of Dandelion.

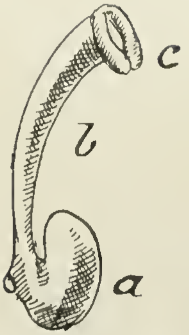


Fig. 561.—Pistil of a Strawberry. (*a*) Ovary. (*b*) Style. (*c*) Lobed stigma.

part of the Strawberry is not a ripened ovary, but the greatly swollen receptacle or *thalamus* of the flower; and the real fruits are the small, dry, seed-like carpels scattered over its surface. In an Apple the edible part is not the ovary alone, but embraces the succulent and enlarged floral receptacle, which also, as in the Strawberry, forms the bulk of the "fruit." The ovary occupies the cavity of this much-distended tube, and is fused with the inner wall of it. The "pips" are the seeds. This form of spurious fruit is termed a *pome* (fig. 566). The chief substance of a fig, again, is its fleshy receptacle or axis, the true fruits being the hard yellow grains borne on the inside of the cavity of the receptacle. In the Mulberry (*Morus*) the bracts of the clustering flowers coalesce with the perianth, and form a succulent matrix for the individual fruits. A mulberry is, in fact, a collection of spurious fruits fused together —in botanical language, a *pseudo-syncarp* (fig. 567).

Other well-known examples of pseudo-syncarps are afforded by the Bread-fruit-tree (*Artocarpus incisa*) and the Pineapple (*Ananassa sativa*). These *collective fruits*, as they are called, must be carefully distinguished from *aggregate fruits*, in which the clustered carpels are derived from a single flower, as in the Raspberry and Blackberry (*Rubus Idæus* and *R. fruticosus*). The raspberry and blackberry, moreover, are *syncarps*, not pseudo-syncarps.

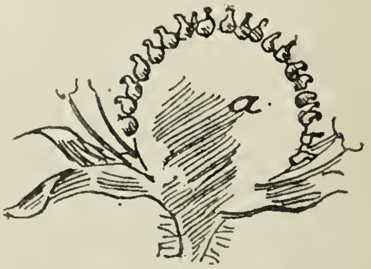


Fig. 562.—Section of an unripe Strawberry: *a* is the enlarged receptacle on which membranous pistils are seated.

Thus we come to true fruits. These may be conveniently divided into three classes. To the first class belong those fruits which break and shed their seeds, or are *dehiscent*; to the second class, those which do not break, or are *indehiscent*; and to the third class, those splitting fruits which in some cases shed their seeds, and in others—the majority of cases—do not. We call these splitting fruits *schizocarps*.

Of the various forms of dehiscent fruits one of the commonest is the *capsule*. Strictly speaking, capsules are fruits with two or more carpels whose pericarp liberates the seeds by toothed

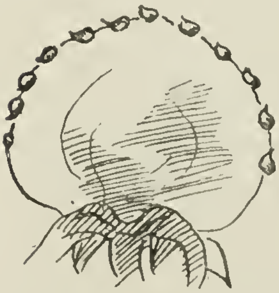


Fig. 563.—Section of a ripe Strawberry, showing the carpels borne on the succulent receptacle.

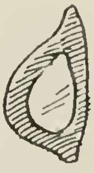


Fig. 564.—One of the carpels in longitudinal section.

or valvular openings, by pores, or by the falling off of a lid; but the term is frequently applied, with more latitude than correctness, to all dry dehiscent fruits. However, as the other forms of capsule have special distinguishing names, we shall here employ the term in its more exclusive sense.

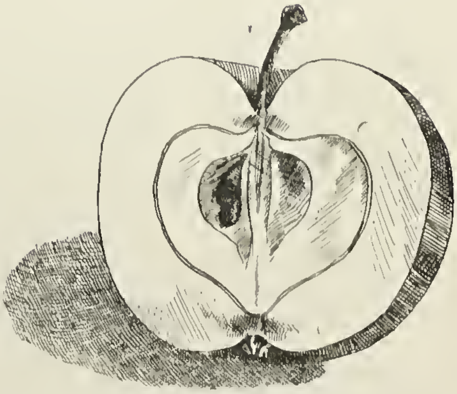


Fig. 565.—Longitudinal section through an Apple.

Good examples of *porous* capsules are found in the Poppy (*Papaver*, fig. 568). The pores are provided with little flaps on the sides, beneath the eaves of a roof-like top, and these flaps move up and close the pores in time of rain, or when the atmosphere is exceptionally moist. In dry weather they open outwards, and as the poppy-heads sway in the breeze the light small seeds get shaken out and scattered over a wide area.

Protective arrangements somewhat similar to the above seem to be a special feature in what are known as *toothed* capsules. The Corn-cockle (*Lychnis Githago*, figs 570, 571) is a case in point. In wet weather its five teeth meet in a point and prevent the entrance of a drop of rain, but on dry days, and when the seeds are ripe, the teeth are curved back. The seeds escape by this opening.

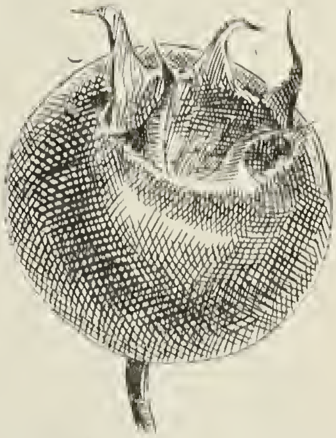


Fig. 566.—Pome of Common Medlar (*Mespilus germanica*).

Compare carefully the capsules depicted in figs. 572-573, which are shown in transverse section, and represent respectively the fruits of the *Iris* and Meadow-saffron (*Colchicum autumnale*); fig. 574 is a fruit of the Common Thorn-apple (*Datura Stramonium*). In figs. 575-577, the three forms are shown diagrammatically. Now in each of these examples it will be noticed that the capsule dehisces in a different manner. In the Iris the capsule splits through the back of its three seed-containing cavities (by its dorsal suture, as we should say), and thus the cavities or *loculi* are broken open. This is known as *loculicidal* dehiscence. *Septicidal* dehiscence is illustrated in the Meadow-saffron. Here the carpel separates into its component ovaries, each of the walls of separation or dissepiments

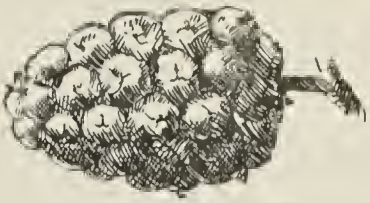


Fig. 567.—Pseudocarp of Mulberry.

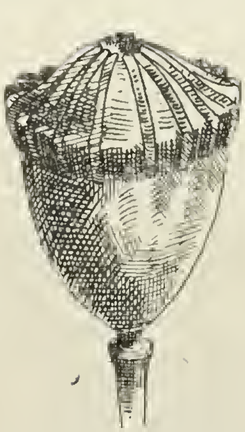


Fig. 568.—Porous capsule of Common Field Poppy (*Papaver Rhœas*).

dividing into two, and thus the loculi remain intact. In the Thorn-apple there is no splitting of the dissepiments, which remain attached to the axis, but the carpellary wall which surrounds them, and to which they are attached, breaks away at the three points of attachment, and so the seeds escape. This is *septifragal* dehiscence.

From the circumstance that, in each of the three examples here given, the pericarp comes away in pieces or valves, the dehiscence is also said to be *valvular*. Allusion has been already made to two very remarkable instances of valvular dehiscence. The sling-fruits both of *Noli-me-tangere* and of *Oxalis Acetosella* come under this category. In the former, the mesocarp consists of large and highly turgid cells, which keep the whole of the capsule in a state of great tension; so that when the fruit is touched the valves fly open, and eject the seeds with considerable force; in the latter, as we have seen, the bursting of the elastic fleshy outer integuments of the seeds is the cause of their expulsion.

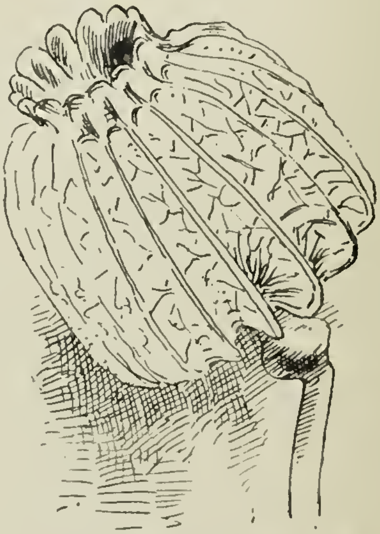


Fig. 569.—Skeleton of seed of a Poppy.

"On the heights of the Kahlenberg, at Vienna, at the edge of the wood," says Kerner, "grows an under-shrub which bears the name of *Dorycnium herbaceum*. It is one of the Papilionaceæ, and develops spherical one-seeded fruits, which ripen in October. I once collected from this plant several twigs laden with fruit, for the purpose of a comparative investigation on which I was engaged, and brought them home and laid them on my writing-table. Next day as I sat reading near the table, one of the seeds of the *Dorycnium* was suddenly jerked with great violence into my face. Shortly afterwards I saw a second, third, fourth, and ultimately about fifty seeds let fly from the small clusters of fruit, and each time I heard a peculiar sound which accompanied the bursting open of the fruits and

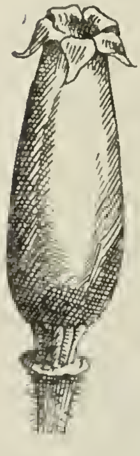


Fig. 570.—Toothed capsule of Corn-cockle, open.

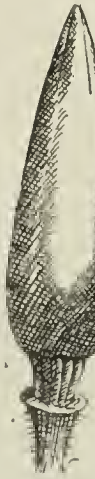


Fig. 571.—The same closed.

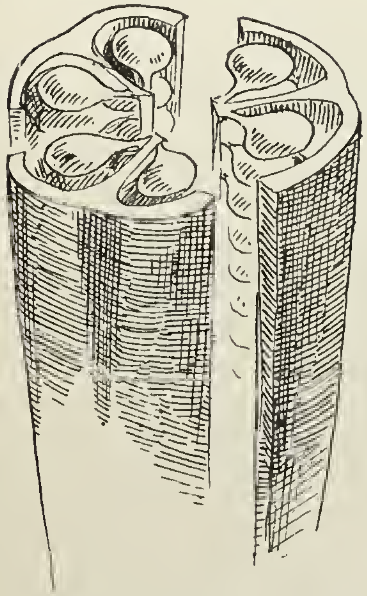


Fig. 572.—Transverse section of capsule of Iris, illustrating loculicidal dehiscence.

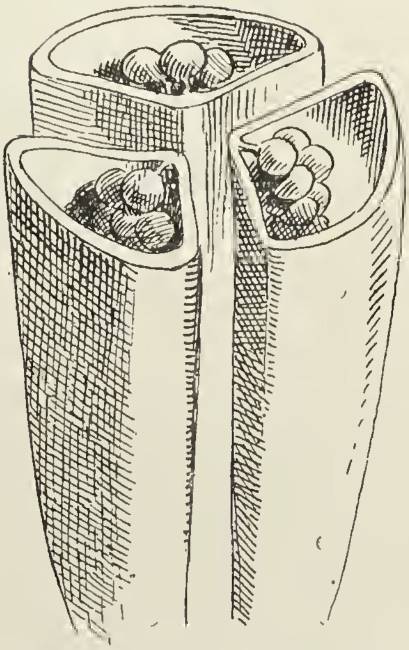


Fig. 573.—Transverse section of Meadow-saffron, illustrating septicidal dehiscence.

ejection of the seeds. The rays of sunshine from the window had evidently heated and dried the fruits, and occasioned this surprising phenomenon." The poet Goethe gives a somewhat similar account of the seed dispersion of *Acanthus mollis*; and methods closely resembling these have been observed in many other plants. Plants with sling-fruits form, in fact, a large group.

A very curious form of capsule is the *pyxis*, in which the splitting takes place transversely, and the top of the capsule falls completely off. The fruits of *Anagallis*, the Pimpernel family, all have this mode of dehiscence; but more striking examples are furnished by the less known tropical genus, *Lecythis*, about which many a quaint story is told. Our drawings (figs. 579, 580) are from specimens of the fruits of *Lecythis validissima* and *L. tumefacta* preserved at Kew. *Lecythos* means an oil-jar, and the popular name for these fruits is "monkey-pots." "The

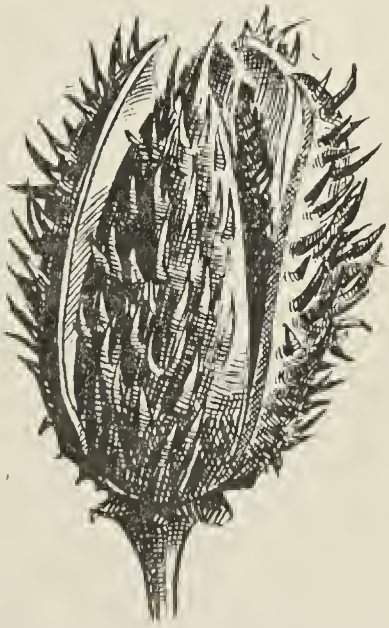
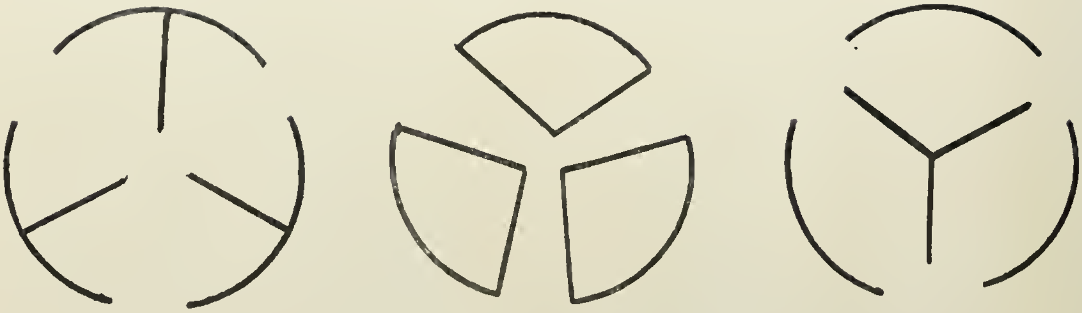


Fig. 574.—Transverse section of capsule of *Datura*, illustrating septifragal dehiscence.



Figs. 575-577.—Diagrammatic representation of figs. 572-574.

great urn-shaped fruits," writes Charles Kingsley, "big enough to serve for drinking-vessels, each kindly provided with a round wooden cover, which becomes loose, and lets out the savoury sapucaia nuts inside, to the comfort of all our 'poor relations.' The pots are used for catching monkeys." "Filled with sugar," says a writer in the *Gardener's Chronicle* (1861), "they are placed on the ground which such animals frequent. The sugar attracts the latter, who pick it out leisurely till they are disturbed, when they insert the paw, grasp as much sugar as it will hold, and endeavour to escape with the prize. But their doubled fist, being larger than the mouth of the pot, cannot be withdrawn, and the monkeys, tenaciously holding the sugar, run off with a pot firmly enclosing one paw. This renders it impossible for them to escape from their pursuers by climbing, and they are easily run down."

The remaining dry dehiscent fruits which are sometimes described as capsules are the follicle, the legume, the siliqua, and the silicula. We will take them in that order.

The *follicle* is a superior, one-celled fruit, containing one or more seeds, which are liberated in most instances by a ventral suture only. *Magnolia glauca* and some other species of *Magnolia* are exceptions. As a rule, several follicles are collected in a cluster at the end of a flower-stalk, but solitary follicles are common in Proteaceæ; and there are a few plants (*e.g.*, the Pæony, fig. 582), normally developing two or more follicles with each flower, which occasionally produce but one. The Columbine (*Aquilegia*) and Larkspur (*Delphinium*) offer good examples of the follicle (figs. 583, 584).

The *legume* or *pod* resembles the follicle in that it arises from a single carpel; but, unlike the follicle, it dehisces at *both* sutures. This is the characteristic fruit of the great order

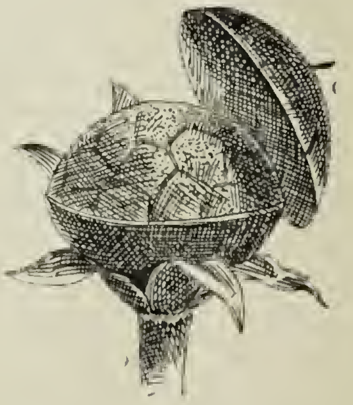
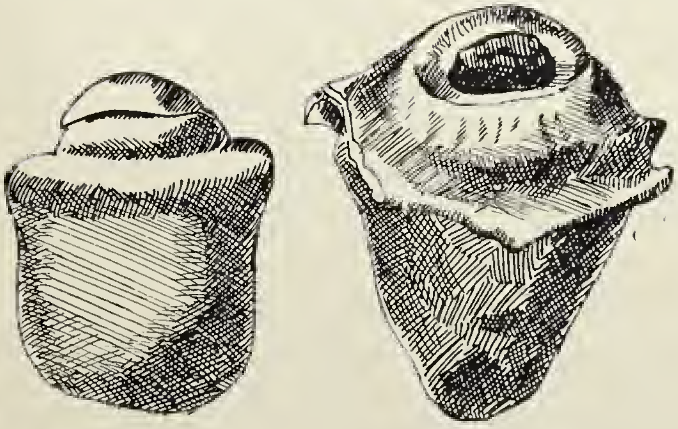


Fig. 578.—Pyxidium of *Anagallis*.



Fruit of *Lecythis validissima.* Fruit of *Lecythis tumefaeta.*

Figs. 579-580.—"Monkey-pots": both of Brazil.

Leguminoseæ, to which the Pea and Bean belong, (fig. 590). The legumes assume a curious twisted form in the small genus *Scorpiurus*, which includes the interesting Caterpillar-plant (*S. vermiculata*, fig. 585), and a spiral form in the Purple Lucerne (*Medicago sativa*, fig. 586). When the pod is contracted in a bead-like (*moniliform*) manner, as in the Gum Arabic-plant (*Acacia arabica*, fig. 587), it is termed a *lomentum.*

The legumes of the Earth-nut (*Arachis hypogæa*, fig. 588) deserve notice on account of peculiarities other than those of form. The specific name *hypogæa* (Greek *upo ge*, under ground) is an allusion to the curious circumstance that the young pods, as they begin to mature, are forced into the earth by a lengthening of the flower-stalks, and ripen their seeds below the ground. This phenomenon is not confined to the Earth-nut, but has been observed in a few other plants—*Trifolium subterraneum*, for example, and the Sweet Violet (*Viola odorata*). The fruits of the latter are not leguminous. Plants with burying fruits, says Kerner, "have always been a source of wonder to botanists, and their number is not large. The best known examples are *Arachis hypogea*, *Cardamine chenopodiifolia*, *Linaria Cymbalaria*, *Phrynium micans*, *Trifolium subterraneum*, and *Vicia amphicarpa*. If these plants were only to bring fruit to maturity underground, or were to draw all their fruits below the ground as soon as the seeds were mature, in order that germination and the development of new plants might ensue at that spot, their behaviour would imply a renunciation of dispersion to any distance, and the phenomenon would be highly enigmatic. The puzzle is satisfactorily solved, however, when we take into account the fact that all these plants invariably have the chance of being dispersed to great distances either before the fruits become concealed in the earth, or by means of a second form of fruit which ripens aboveground, and is evidently adapted to being scattered abroad through the

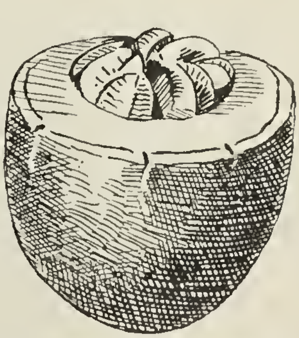


Fig. 581.—Fruit of *Bertholletia excelsa*, the Brazil-nut Tree. Each fruit of this tree contains from fifteen to twenty triangular seeds—the Brazil nuts of commerce.

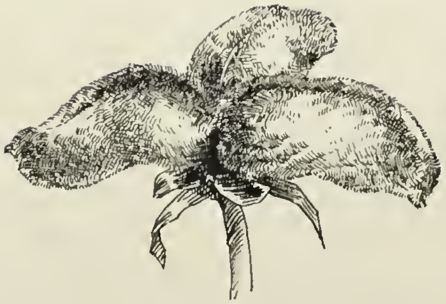


Fig. 582.—Follicles of Pæony.

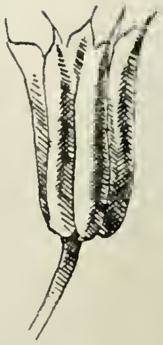


Fig. 584.—Follicles of *Delphinium grandiflorum*.

agency of animals, or by means of aerial or aqueous currents." *Linaria Cymbalaria* grows down the face of old walls, and its capsule-stalks twist until the capsule is brought to a chink, into which it is thrust. Here, when the seeds are ripe, the capsule opens and discharges the seeds under conditions favourable for their germination.

The *siliqua* consists of two carpels, the exposed walls of which break away, leaving the seeds attached to an upright central framework, the *replum*; on which is stretched a delicate membrane which forms the false septum of the fruit. Siliquas are characteristic of the Crucifers, and usually take a long, narrow form, as in the Wallflower (*Cheiranthus Cheiri*) and Stock (*Mathiola*, figs. 589, 589A). In the genus *Lunaria*, the well-known Honesty, the form is broadly elliptical (fig. 591). The force and suddenness with which the siliquas in some species of Crucifers fly open greatly facilitate the dispersion of the seeds.

The siliquas of the so-called "Rose of Jericho" (*Anastatica Hierochuntica*, fig. 592) are of unusual form, and the whole plant at the time of fruiting exhibits phenomena which are exceedingly curious. Its branches, which are ordinarily of a spreading character, curve inwards when the fruits are ripe, and form a kind of cage or trellis about the siliquas. This position is maintained, and the siliquas remain closed, in a dry atmosphere, but directly the air becomes moist, the branches straighten out again, and the siliquas open. The seeds are thus fully exposed, and with the first rainfall are washed out of the fruit-valves and dispersed over the land.

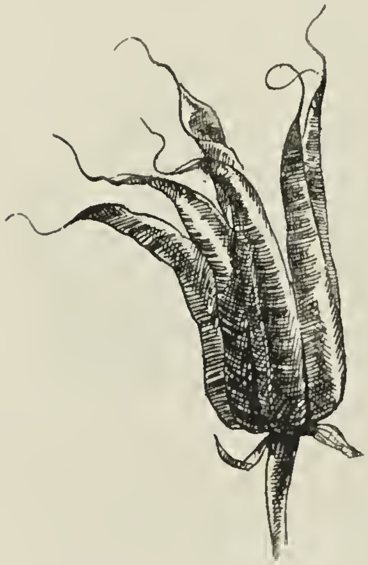


Fig. 583.—Follicle of Columbine.

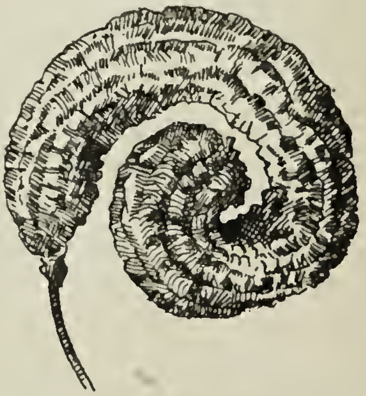


Fig. 585.—Twisted legume of Caterpillar-plant.

The *silicula* differs in no essen-

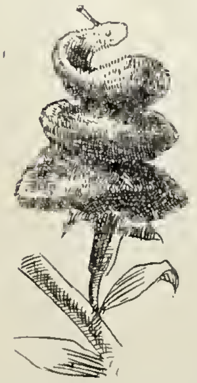


Fig. 586.—Spiral legume of Lucerne.

tial particulars from the siliqua. The former term is simply a diminutive of the latter—a fact which gives the key to a definition. Briefly, indeed, a silicula is a broad and very short siliqua. The ubiquitous Shepherd's Purse (*Capsella Bursa-Pastoris*) offers the readiest example of this form of fruit; but, for variety's sake, we have chosen for illustration a silicula of the Evergreen Candytuft (*Iberis sempervirens*, fig. 593).

It will be noticed that the capsule, follicle, legume, siliqua, and silicula are all forms of *dry* dehiscent fruits. Fleshy or succulent pericarps have no place in this five-fold group. Nevertheless there are two forms of dehiscent fruits in which the characteristic alluded to is met with—namely, the succulent capsule and the dehiscent drupe.

The green prickly husk of the Horse-chestnut (*Æsculus Hippocastanum*, fig. 594) is a pericarp, which, when ripe, splits into valves and sets free the seeds. It is a *succulent capsule.* So, too, is the unarmed fruit of the nearly related Sweet Buckeye (*Pavia flava*, fig. 595), whose native habitat is the mountainous districts of Tennessee and North Carolina. Figs. 595-597 show the fruit whole and in section; the drawings were made from young immature fruits.

The Walnut (fig. 598) is a *dehiscent drupe.* Its green fleshy covering consists of epicarp and mesocarp. The hard shell enclosing the seed is endocarp. The fleshy covering, which is rich in tannin, protects the unripe seed from nut-cracking animals, but when the latter is ripe, the envelope splits, and the so-called "nut" (whose development is really analogous with that of a plum-stone) becomes accessible.

The curious hooked fruits of the Martynias are *sub-drupaceous capsules.* Frank Buckland used to say of *Martynia proboscidea* (fig. 599) that its fruits must have been created "for the express purpose of sticking to the tails of the wild horses that roam the plains of South America"; and certainly one of the objects of the hooked spines and bristles of fruits of whatever kind is their dispersion by animals. Kerner estimates that the fruits and seeds of about 10 per cent. of all Flowering Plants are provided with processes of this description, some of which take the form of hooks and others of barbs. The Goose-grass (*Galium Aparine*), a long, weak, straggling plant very common in our hedges and thickets, has small fruits (dry, indehiscent pericarps, in this case) which are literally covered

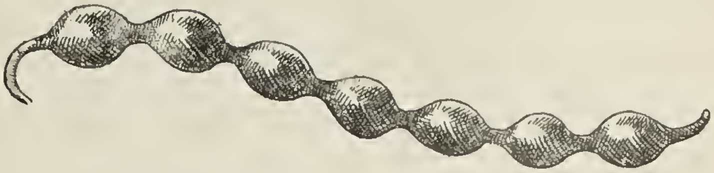


Fig. 587.—Lomentum of Gum Arabic-tree.

with hooked bristles. Country people call the plant "cleavers," from its habit of cleaving to objects with which it is brought in contact, and children like to throw the hispid fruits at one another for the fun of seeing them "stick." In the Burweed (*Xanthium*, fig. 601) the hooks are borne upon the hardened involucre, which grows about and covers the one-seeded fruit. The capsules of the African Grapnel-plant (*Harpagophytum procumbens*) are provided with claw-like spines of a particularly powerful kind, which grasp the hoofs of unwary animals in the Orange River region where the plant abounds, causing them the greatest pain; nor is there relief from the torment till the capsule splits up to release the seeds.

Thus far our attention has been mainly confined to dehiscent fruits; we will now speak a little of those which never open spontaneously, or, in other words, are *indehiscent*. It will be seen as we proceed that the provisions for dispersion, in the way of hairs, curved bristles, and hooked spines on the one hand, and of wings, plumes, etc., on the other, are far more common in indehiscent than in dehiscent fruits; and the reason is obvious. The pericarp which releases its seeds spontaneously at the time of ripening has done its work when dehiscence has taken place, and the seeds are left, so to speak, to their own resources. The broken, empty seed-case has no further

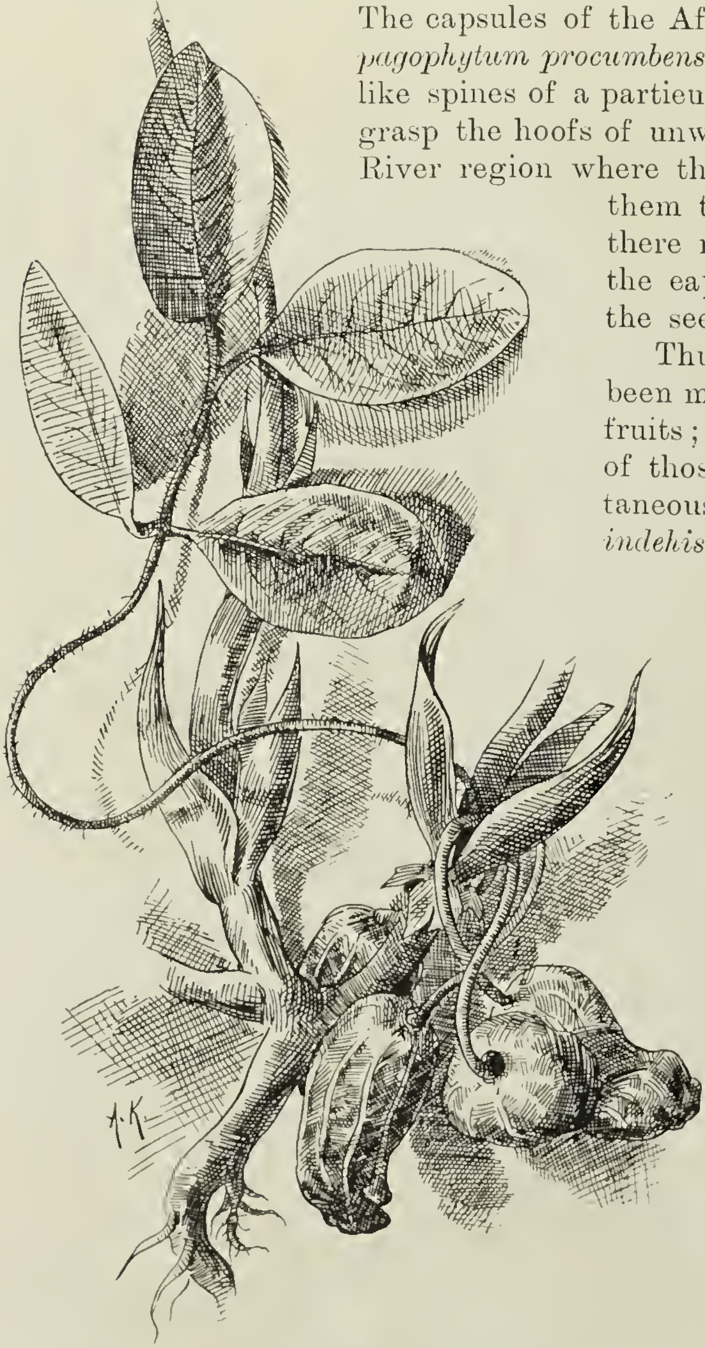


Fig. 588.—Earth-nut.

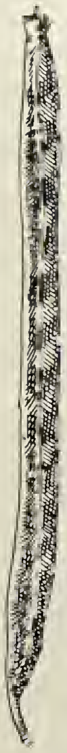


Fig. 589.—Siliqua of Stock.

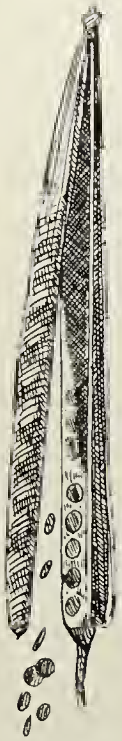


Fig. 589A.—The same, dehiscing.

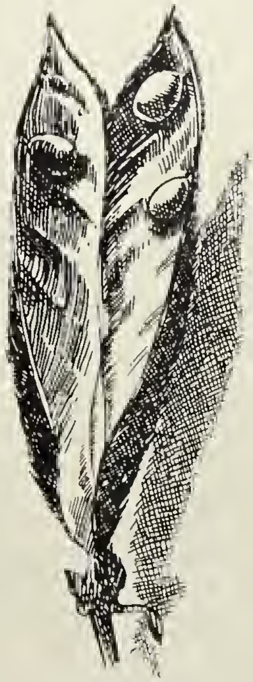


Fig. 590.—Legume of Lupine (*Lupinus*).

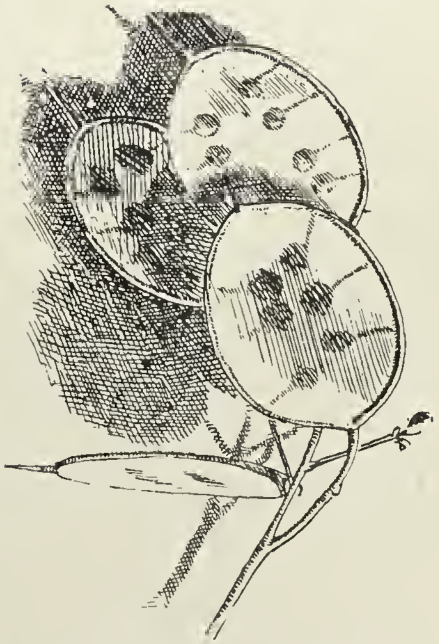


Fig. 591.—Siliquas of *Lunaria annua*.

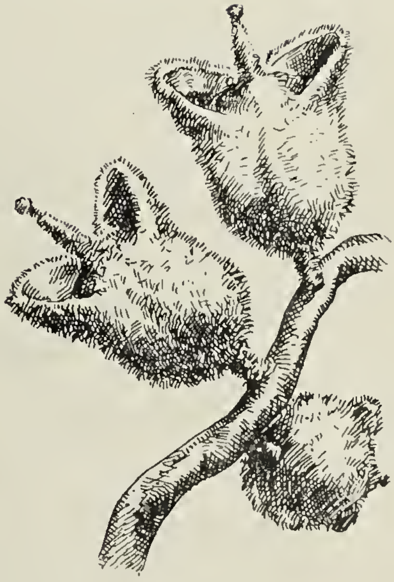


Fig. 592.—Fruiting branch of "Rose of Jericho."

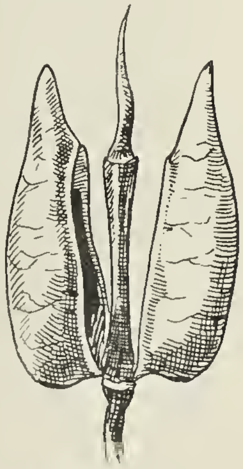


Fig. 593.—Silicula of Evergreen Candytuft.

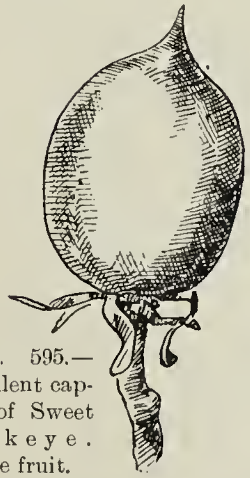


Fig. 595.—Succulent capsule of Sweet Buckeye. Whole fruit.

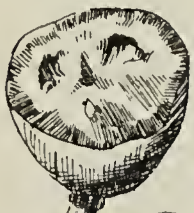


Fig. 596.—Same in transverse section.

Fig. 597.—A seed of same.

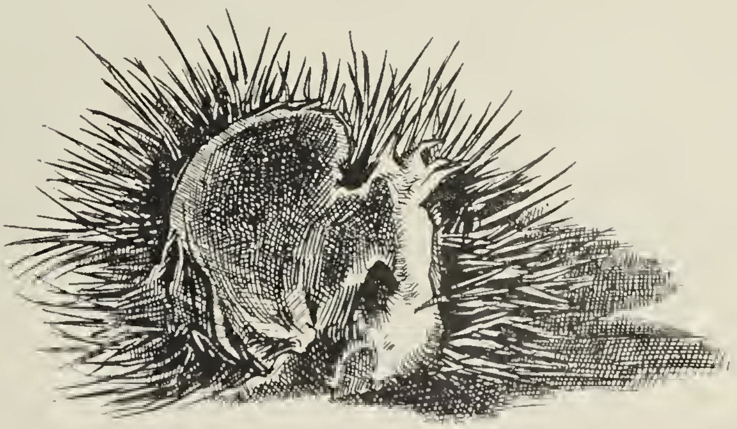


Fig. 594.—Prickly husk (pericarp) of Horse-chestnut laid open. The chestnut (*i.e.*, the seed) has been removed.

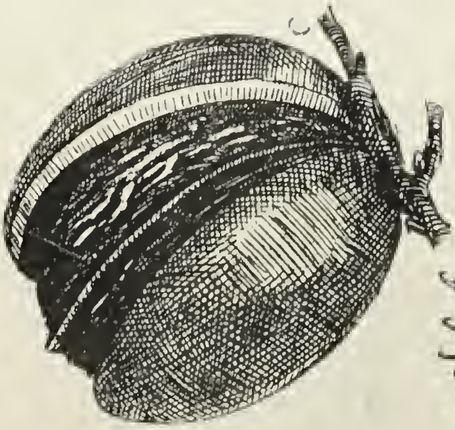


Fig. 598.—Walnut: a dehiscent drupe. The fleshy epicarp and mesocarp are bursting to liberate the seed, which is still enclosed in the hard endocarp or shell.

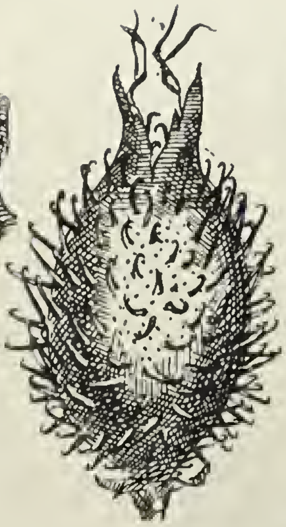


Fig. 601.—Fruit of Broad-bearded Burweed, with hook-clad involucre.

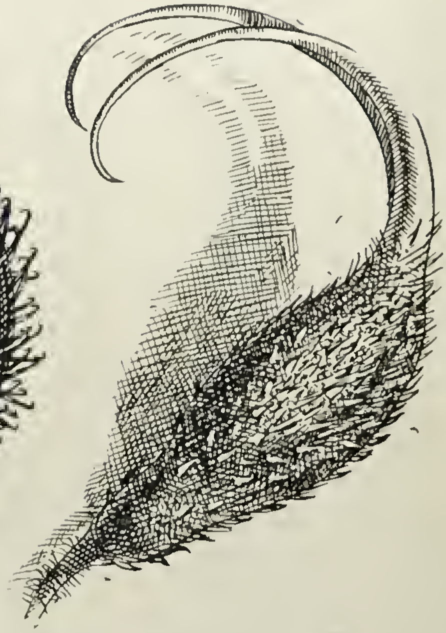


Fig. 599.—Hooked fruit of *Martynia proboscidea.*

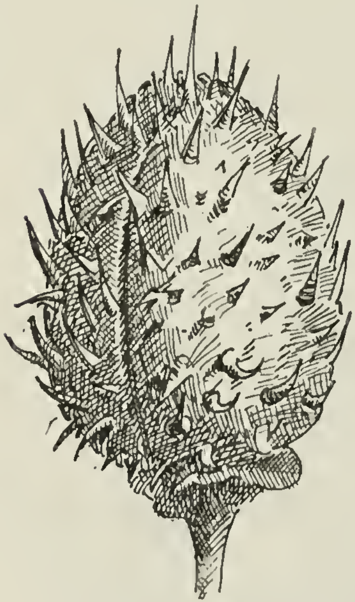


Fig. 600.—Capsule of *Datura Stramonium.*

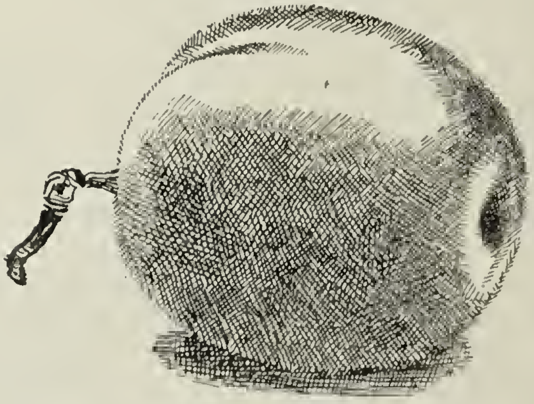


Fig. 605.—Drupe of Plum (*Prunus*)

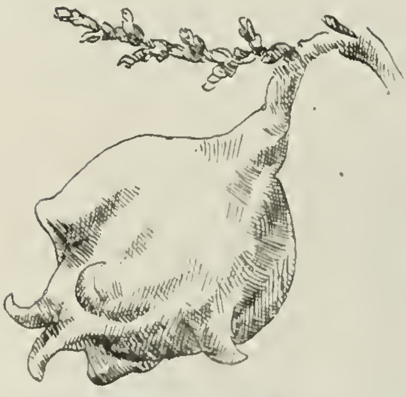


Fig. 602.—Cone of Chinese *Arbor vitæ* (*Thuja orientalis*).

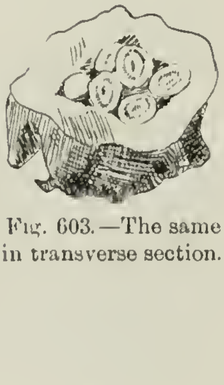


Fig. 603.—The same in transverse section.

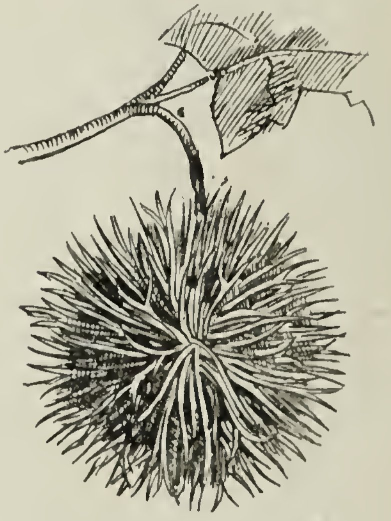


Fig. 604.—Spined fruit of *Megarrhiza californica.*

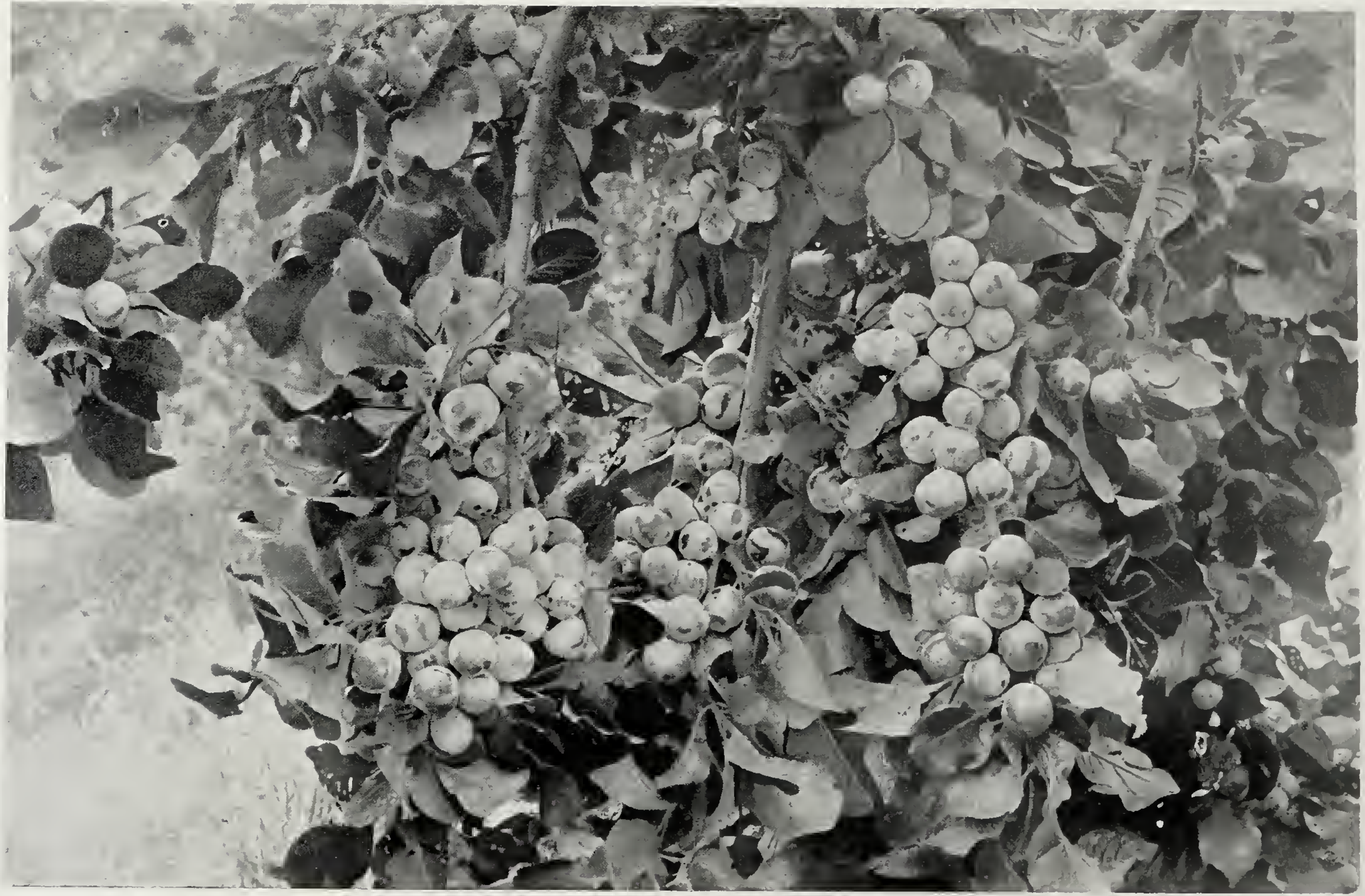


Photo by W. Reid, Wishaw.

YELLOW PLUMS, FRUIT OF AN AMERICAN SPECIES OF PLUM-TREE (*Prunus Americana*).

PLATE XXVI.

use. But in the case of an indehiscent fruit, where pericarp and seed do not part company on the ripening of the latter, a contrivance of some kind to assist dispersion is clearly a valuable provision.

Take a stone-fruit, such as the plum, by way of illustration (fig. 605). A plum is a fleshy, indehiscent fruit called a *drupe*, with a stony endocarp, which invests the "kernel" or seed (fig. 606). (This may be accepted as a definition of a drupe.) Now, as the seed of the plum matures, the fleshy mesocarp, or sarcocarp, becomes more succulent and loses its acidity, while the green epicarp, hitherto only to be distinguished with difficulty from the surrounding leaves, assumes a yellow, red, or purple colour, and so becomes very conspicuous. By reason of these changes, animals—particularly birds—are attracted to the fruits, which they devour greedily. The seeds, thanks to their environment of stony endocarp, resist digestion, and in many cases are transported to great distances. The cherry, apricot, peach, and a host of other drupaceous fruits undergo very similar transformations, and are distributed by similar means.

The fruit of the Coco-nut Palm (*Cocos nucifera*), with its fibrous mesocarp, is also a drupe, though some botanists speak of it as a *nut*. This is one of the fruits disseminated by water—a fact which accounts for the prevalence of palm-groves on the coral islands of the Pacific. In the vicinity of Key West, an island of the Florida reefs, and as far north as Jupiter Inlet, two hundred miles from Key West, the sandy beach is lined with Coco-nut Palms, which owe their presence there to the wrecking of a vessel which had a cargo of the nuts on board. The Double or Sea Coco-nut (*Lodoicea Seychellarum*, fig. 608) is distributed by similar means. "The Seychelles," says Miss Gordon Cumming in her *Two Happy Years in Ceylon*, "contribute a fine specimen of their own particular Palm, the *Coco-de-mer* [Sea Coco-nut], which was so long known only by the great double nuts (shaped like a kidney when cut open) which tidal currents floated far out on the Indian Ocean and to the shores of the Maldive Islands, where they were occasionally picked up by sailors and brought home to puzzle botanists. It was not till last [*i.e.*, the

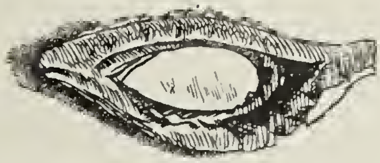


Fig. 607.—Section through the stone of the same.

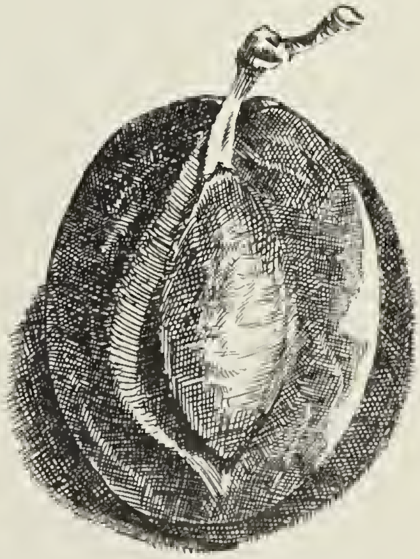


Fig. 606.—Section of a Plum.

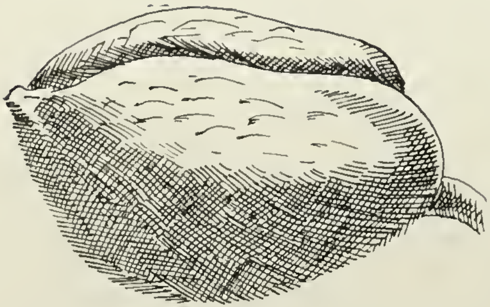


Fig. 608.—Fruit of Sea Coco-nut Palm or *Coco-de-mer.*

eighteenth] century that the parent Palm was discovered in the Seychelles, and it was found that the Palm, with a fruit like twin coco-nuts, bears a crown of huge fan-shaped leaves, akin to those of the Palmyra Palm, crowning a stem a hundred feet high."

Another common form of indehiscent fruit is the *berry.* In a berry the whole of the seed-case or pericarp becomes fleshy or succulent—there is no stony endocarp as in the drupe. The grape (fig. 609), currant, gooseberry, and mistletoe are well-known examples. The gourd is really a huge berry with a hard outer layer, but it is more often called a *pepo* (fig. 610). Dispersion of the seeds of berries is effected largely by animals, under circumstances very similar to those attending the seed dispersal of drupaceous fruits. The seed-coats resist the action of digestive juices as effectually as does the stony endocarp of the plum or cherry.

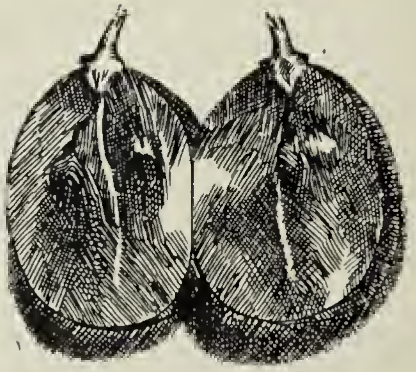


Fig. 609.—A Grape laid open longitudinally to show the seed embedded in the succulent flesh, and attached to the placentas by long funiculi.

Few indehiscent fruits are more puzzling on a first examination than the orange. The development of the three layers of the pericarp is very remarkable, and forms one of the characteristics of a remarkable kind of fruit—the *hesperidium.* The peel of the orange consists of epicarp and mesocarp; while the membranous partitions which project internally towards the centre of the fruit, and divide off the juicy pulp into separate groups of cells (the misnamed "quarters" of the orange) consist of endocarp. The pulp itself, in which the "pips" or seeds are embedded, is a development of succulent cells (internal hairs) from the inner lining of the ovary—*i.e.*, from the endocarp. The lemon, shaddock, etc., have the same distinguishing feature, and are equally good examples of the hesperidium.

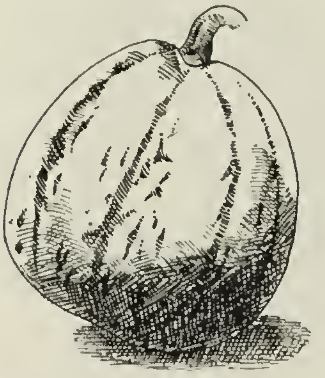


Fig. 610.—Pepo of a Gourd (*Cucurbita*).

The three sorts of indehiscent fruits which we have been considering—drupe, berry, and hesperidium—are all succulent; the remaining kinds are dry. They are the achene, nut, caryopsis, and cypsela.

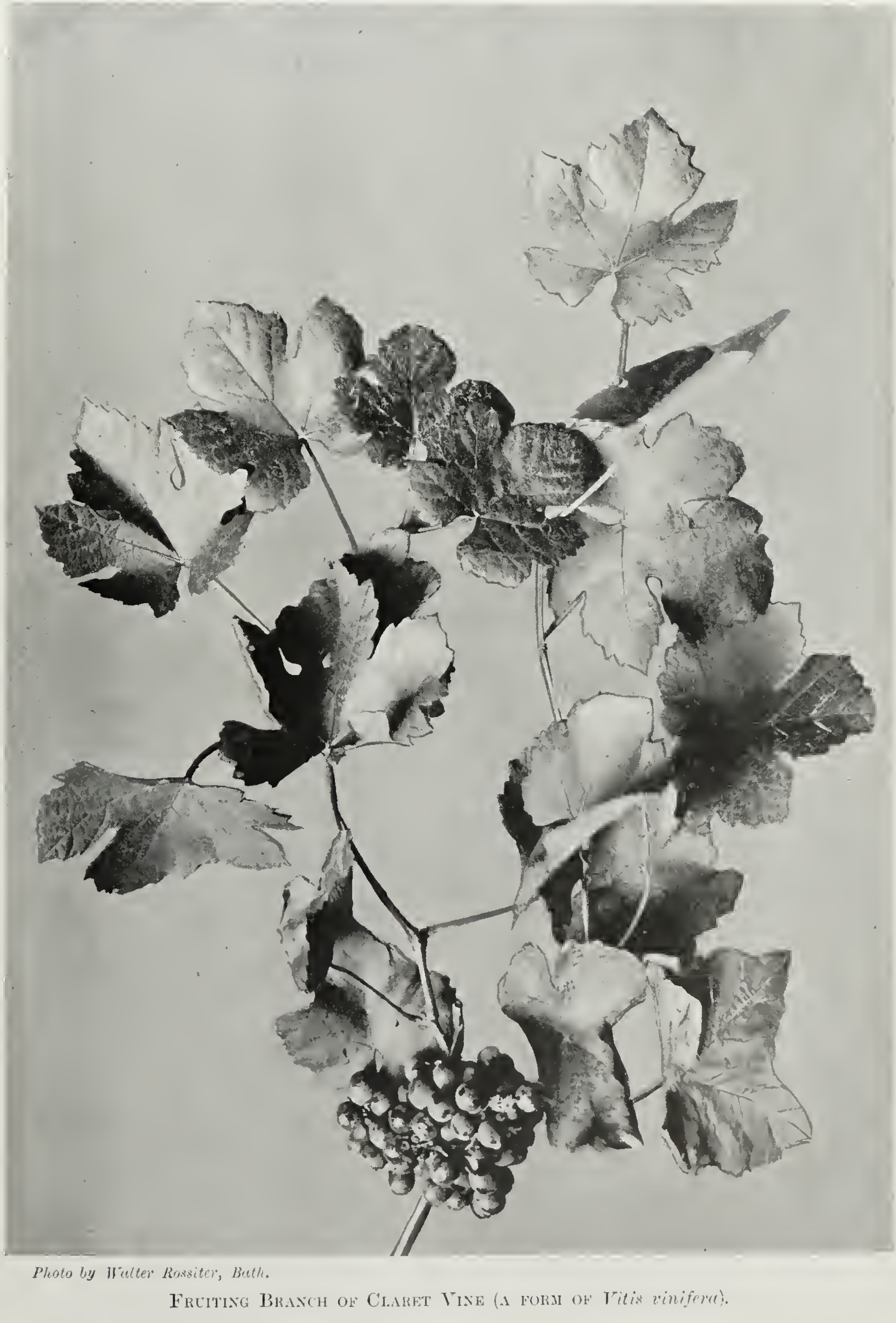


Photo by Walter Rossiter, Bath.

Fruiting Branch of Claret Vine (a form of *Vitis vinifera*).

Plate XXX.

A dry indehiscent fruit developed from a pistil with single carpel is an *achene*; if the pericarp is thin and leathery, and not adherent to the seed-coat, it is an achene; if hard and woody, a *nut*. Any dry one-seeded indehiscent fruit with a hard endocarp is called a nut. As a rule, a nut has but one chamber, the partition-walls disappearing by atrophy as the fruit develops. The fruits of the Urchin-crowfoot (figs. 612, 613) are achenes; the fruits of the Hazel (*Corylus*, fig. 614) are nuts. The husk which partly envelops the hazel-nut is formed by greatly enlarged bracts.

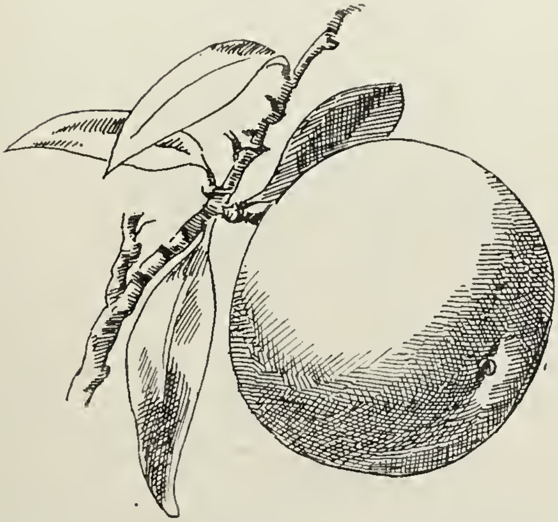


Fig. 611.—Fruit of Myrtle-leaved Orange (*Citrus Aurantium var. myrtifolia*): a hesperidium.

In the Oak (*Quercus*, fig. 615) the nuts, usually called acorns, are seated in cups or *cupules* of bracts, which, curiously enough, are only formed after fertilisation. The order *Cupuliferæ* derives its name from these vegetable cups. Beech-nuts, the fruits of *Fagus sylvatica*, are contained in a spiky husk—the enlarged four-partite involucre of bracts—which, on a superficial view, might be mistaken for the pericarp. Each involucre usually contains two nuts, which are sharp-cornered and triangular, and which, on the splitting of the husk in the autumn, fall to the ground.

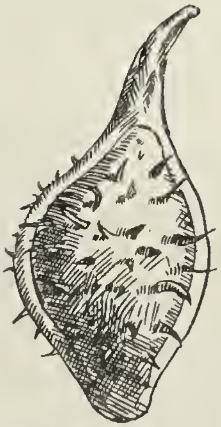


Fig. 612.—Achene of Urchin-crowfoot (*Ranunculus arvensis*).

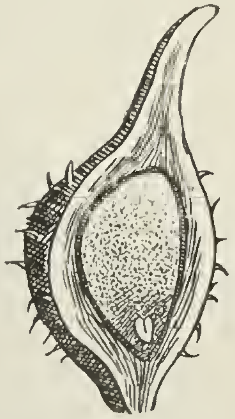


Fig. 613.—The same in section.

Fruit dispersion in cupuliferous plants is largely assisted by animals. "Many noble oaks," says a writer in the *Zoologist*, quoted by Dr. Cooke, "have been planted by the squirrel, who unconsciously yields no inconsiderable boon to the domain he infests. Towards autumn this provident little animal mounts the branches of Oak-trees, strips off the acorns and buries them in the earth, as a supply of food against the severities of winter. He is most probably not gifted with a memory of sufficient retention to

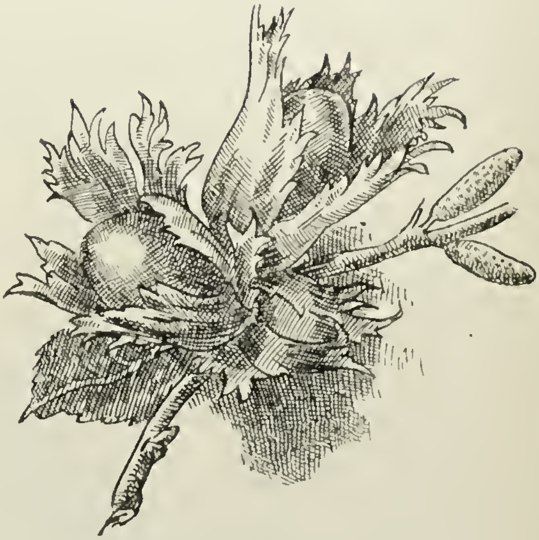


Fig. 614.—Fruit of Hazel.

enable him to find every one he secretes, which are thus left in the ground, and springing up the following year, finally grow into magnificent trees. Pheasants devour numbers of acorns in the autumn, some of which, having passed through the stomach, probably germinate. The nut-hatch in an indirect manner also frequently becomes a planter. Having twisted off their boughs a cluster of beech-nuts, this curious bird resorts to some favourite tree, whose bole is uneven, and endeavours by a series of manœuvres to peg it into one of the crevices of the bark. During the operation it oftentimes falls to the ground, and is caused to germinate by the moisture of winter. Many small beeches are found growing near the haunts of the nut-hatch, which have evidently been planted in the manner described."

A dry fruit whose leathery pericarp closely adheres to the seed-coat is termed a *caryopsis*. This is the characteristic fruit of the family of Grasses. The Wheat-plant (*Triticum*) presents a good type of the caryopsis. A full-grown and perfect grain of wheat will, on examination, be found to resemble the accompany figures (figs. 616, 617). In form it is a compressed oval, and is enclosed, firstly, in certain chaffy scales, which are easily separated from it; then the membranous pericarp or ovary; and within that, the *testa*, which is the outer integument of the seed, and to which the pericarp closely adheres. Thus a grain of wheat is not merely a seed. It

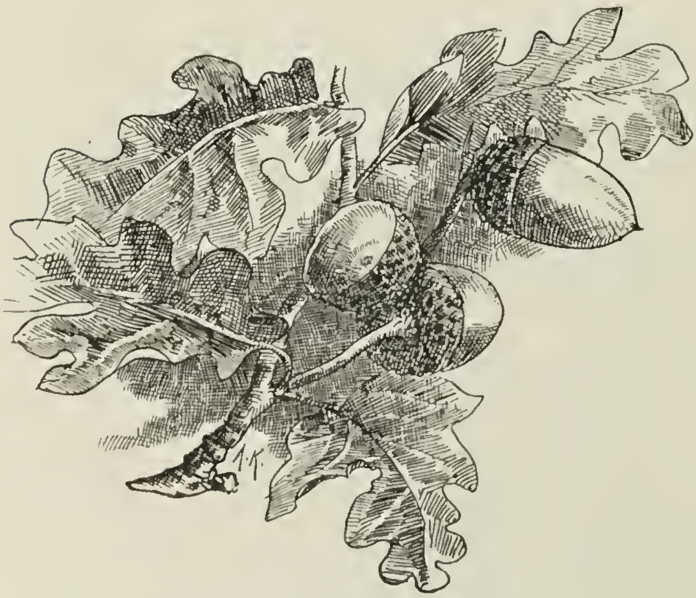


Fig. 615.—Acorns of Oak.

consists of a pericarp as well as seed, and consequently is a true fruit. Fig. 618 shows one of the caryopses of a curious Indian Grass (*Coix Lachryma*), popularly known as Job's Tears. The peculiar heavy grey pearly fruits, hanging in clusters out of their sheaths, give this plant an unique appearance.

It is to be noticed that the caryopsis only differs from the achene in one particular. In the former, the pericarp is closely adherent to the testa of the seed; in the latter there is no adhesion whatever. Both are superior fruits (the ovaries being free from and rising above the perianth); and in this respect, and this only, they differ from the *cypsela*, which is inferior.

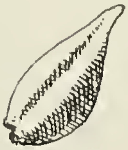


Fig. 616.—Grain of Wheat: a caryopsis.

The *cypsela* is the characteristic fruit of the great order of Composites; and its usual addition of a stipitate or sessile pappus admirably adapts it for dispersion by the wind (figs. 619-621).

> Each is commissioned (could we trace
>   The voyage to each decreed)
> To cónvey to some distant place
>   A pilgrim seed.

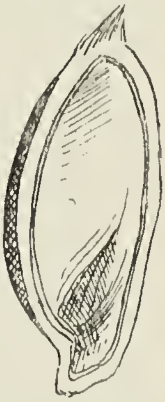


Fig. 617.—Vertical section of same.

Johnston's *Botany of the Eastern Borders* contains some apposite remarks on the wind dispersion of plumed cypselas, and usefully supplements what has been already said on this subject in our preliminary remarks (p. 353). "Elevated on the apex of a long beak," says this writer, "the parachute of the seed of the Goatsbeard (*Tragopogon pratensis*) consists of a number of slender spokes, which diffuse themselves circularly, and are 'telarly interwoven,' somewhat after the fashion of the spider's web. This comparatively intricate structure is given as a countervail to the great size and weight of the seed. The down of Dandelion is supported on a long and slender pedicel, and is an object of vulgar admiration; but it scarcely equals in beauty the similarly patterned fruit of the *Helminthia*. The Thistle's down is, on the contrary, sessile—the threads being sometimes only spinous, at other times plumed like a feather—and the down of the latter is peculiarly light. The coronet of the Carline-thistle (*Carlina*) is remarkable for its elegance and circular spread and plumage, and buoys easily its silky coated seed [*i.e*, fruit]. In the Sow-thistles (*Sonchus*) what we most admire is the ribbed and striated seeds [fruits], but the down that diffuses them is abundant and of pure

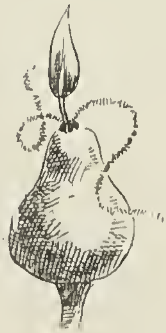


Fig. 618.—Caryopsis of Job's Tears.

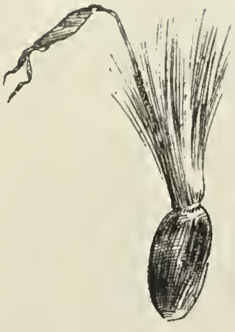


Fig. 619. — Sessile pappus of Milk-thistle (*Carduus marianus*).

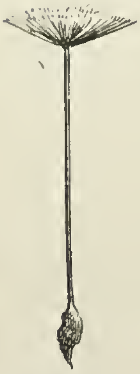


Fig. 620.— Stipitate pappus of Dandelion (*Taraxacum*).

whiteness. The seeds [fruits] of the Coltsfoot (*Tussilago*) afford an example of a structure, common in the order, where the seed [fruit] is surmounted by a tuft of silken hairs, armed at regular intervals with a series of denticles or spines, only visible with a good magnifier. We have a contrast to this in the curious fruit of the Blue-bottle (*Centaurea Cyanus*), which has a small tuft of asbestine spines at the base, and a large but short tuft of rigid stout lanceolate spines on the top, the edges of each of them indented with close and sharp serratures like a saw. This tuft cannot float the seed in the air, but it will obviously direct and hasten its descent into the soil, and it will be remarked that the forward direction of the spines must be opposed to every influence to cast them up again, after having been buried under the surface."

We have now dealt with two of the three great classes into which all true Phanerogamic fruits may be divided; it remains only to speak of the third class—viz., the splitting fruits, or *schizocarps.*

Schizocarps are multiple, usually indehiscent, fruits, which split into one-seeded portions called *mericarps*, resembling nuts or achenes. Each of these portions is itself a true fruit. The splitting may be either longitudinal or transverse; and, of course, the number of parts into which a given schizocarp will divide is determined by the number of its seeds. One with two seeds will split into two parts; another with five seeds, into five parts; and so forth: and this fact has led to the classification of schizocarps into bipartite, tripartite, quadripartite, quinquepartite, and multipartite.

The well-known fruit of the Maple (*Acer*, fig. 622) is a bipartite schizocarp. Its two brown-winged mericarps are known as *samaras*—a name applied to all winged mericarps. In the double fruits of many Umbelliferous plants, the mericarps separate at their lower parts, but remain attached at their apex to a fork-like filiform process, the *carpophore*, as is well shown in the Samphire (*Crithmum maritimum*, fig. 624). Bipartite schizocarps which follow this type are known as

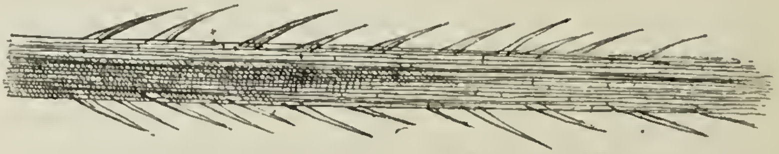


Fig. 621.—Portion of a hair from the pappus of a Milk-thistle.

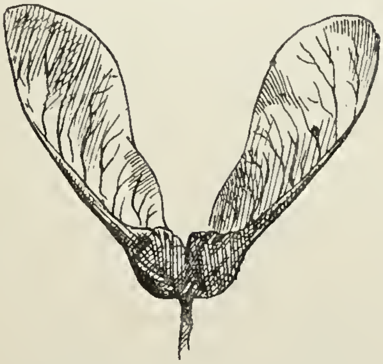


Fig. 622.—Samara of Maple.

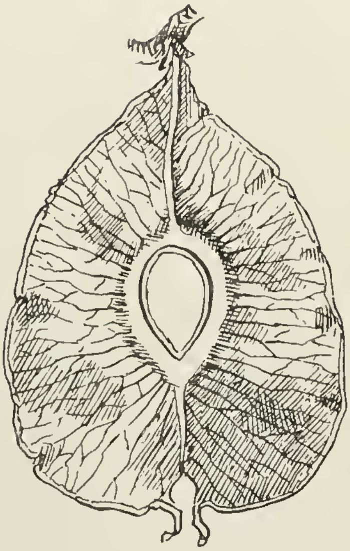


Fig. 623.—Samara of Elm (*Ulmus campestris*); the fruit in longitudinal section.

cremocarps or hanging fruits. In some Umbelliferæ the cremocarps are winged.

Winged fruits and seeds (for we may speak of them together) are adapted for dispersion by the wind. They reach their highest development in the Trumpet-flowers (*Bignoniaceæ*), where the large wings extend three or four inches, "and the seeds float like a large butterfly, wafted from place to place, until a secure home is reached." In many—perhaps most—cases, the wings are not able to sustain the fruits in the air unless a pretty strong wind is blowing; but it must not be forgotten that the wind is the great agent for detaching the fruits from the parent tree, and the same gust which loosens a cluster of samaras from the bough may sweep them many yards through the air before its force is spent.

The other kinds of splitting fruits named above require but little description, and the accompanying illustrations will help to fix their distinctive features in the memory. Fig. 625 shows a tripartite, and fig. 626 a quadripartite schizocarp—the former of the Garden Nasturtium (*Tropæolum majus*), the latter of the Black Horehound (*Ballota nigra*). Two quinquepartite schizocarps are depicted in fig. 627—one of them in the act of splitting. They are fruits of the Bloody Cranesbill (*Geranium sanguineum*). Fig. 628 is a multipartite schizocarp of the Common Mallow (*Malva sylvestris*).

Like the Touch-me-not Balsam (*Impatiens Noli-me-tangere*), of which we have already given some account (p. 352), the fruits of the Bloody Cranesbill are sling-fruits. "If you would wish to catch the *Geranium* in the act of sowing its seed," says Dr. Lindley, "gather a little branch of the ripe fruit on a fine summer's morning before the dew

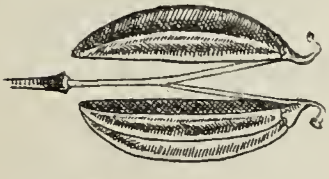


Fig. 624.—Cremocarp of Sea-samphire.

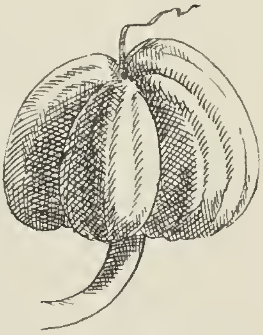


Fig. 625.—Tripartite schizocarp of *Tropæolum majus*.

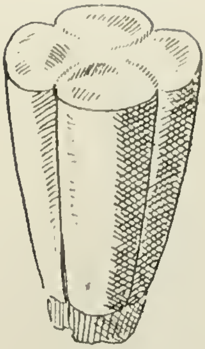


Fig. 626.—Quadripartite schizocarp of Black Horehound.

is off it, and put it in the sun. By degrees the fruits will dry, and if you watch them, you will be surprised by some of them, on a sudden, emitting a snapping sound, and you may see first one and then another of the carpels quickly curving upwards towards the top of the style, opening at the same time by their face, so as to let this seed drop out." All this commotion is caused by the elongation of the axis of the style *after* its five-partite outer layer (to the base of which the carpels are attached) has ceased to grow. A state of great tension is thus produced, and when the splitting takes place the carpels are actually pulled out by the roots, whereupon they roll up upon themselves as though frightened at what they have done. In the Marsh-cranesbill (*G. palustre*) the contraction is so violent that the seeds are hurled to a considerable distance.

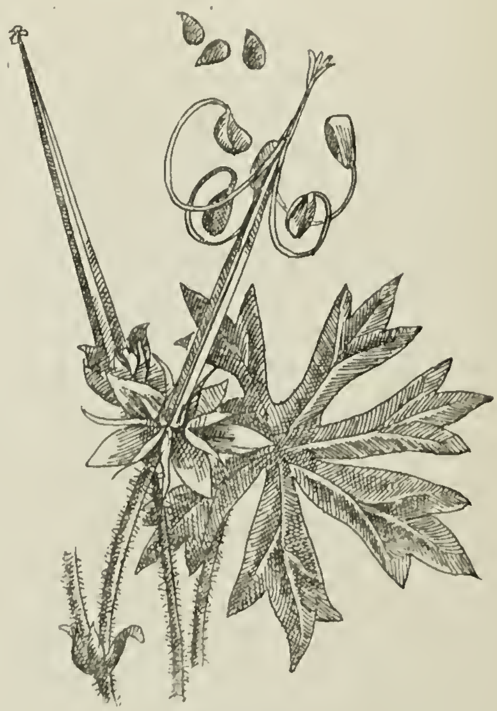


Fig. 627.—Sling fruits of Bloody Cranesbill.

A minute description of the external forms and subsidiary appendages of the *seeds* of plants hardly falls within the scope of the present volume. The testa, or outer integument, may be smooth, as in the Bitter Cucumber (*Citrullus Colocynthis*, fig. 629); reticulated, as in Larkspur (*Delphinium*, fig. 631), papillose, as in the Corn-cockle (*Lychnis Githago*, fig. 630); ridged, as in the Rangoon Creeper (*Quisqualis indica*, fig. 632); or woolly, as in the Brazilian climbing shrub, *Trigonia villosa* (fig. 633). The seed of *Leptodermis lanceolata* (fig. 634), a Bengalese evergreen shrub, is enclosed in a reticulated sac of endocarp; while others are more or less enveloped in a remarkable appendage known as the *arillus*, which springs from their

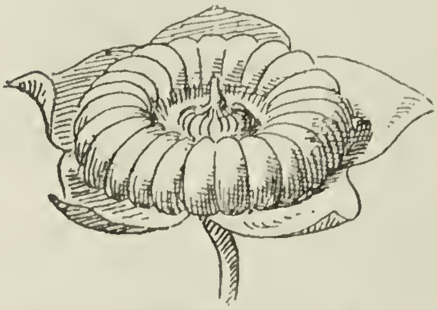


Fig. 628.—Multipartite schizocarp of *Malva sylvestris*.

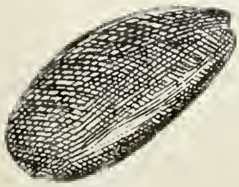


Fig. 629.—Smooth seed of Bitter Cucumber.

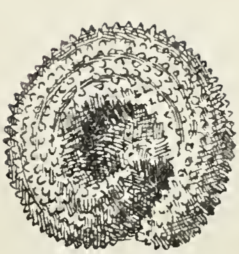


Fig. 630.—Papillose seed of Corn-cockle.

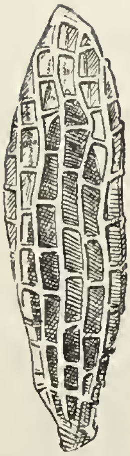


Fig. 634.—Seed of *Leptodermis lanceolata*, a Bengalese evergreen shrub, enclosed in reticulated sac of endocarp.

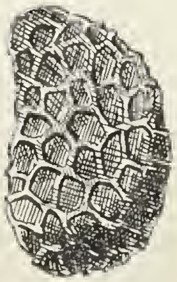


Fig. 631.—Reticulated seed of Larkspur.

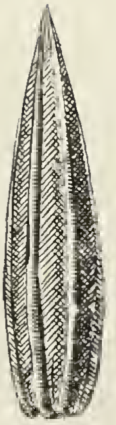


Fig. 632.—Ridged seed of Rangoon Creeper.

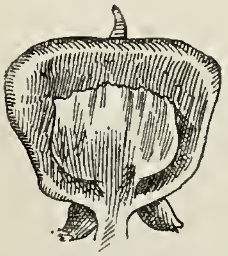


Fig. 639.—Ovuliferous scale of Scotch Pine, seen from below, with its two ovules.

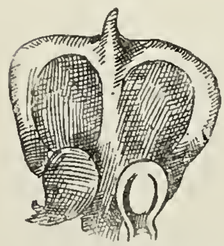


Fig. 640.—The same seen from above. One of the ovules is seen in section.

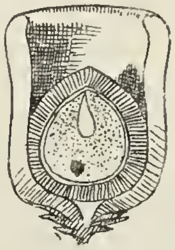


Fig. 636.—Longitudinal section of ripe seed and arillus of Yew.

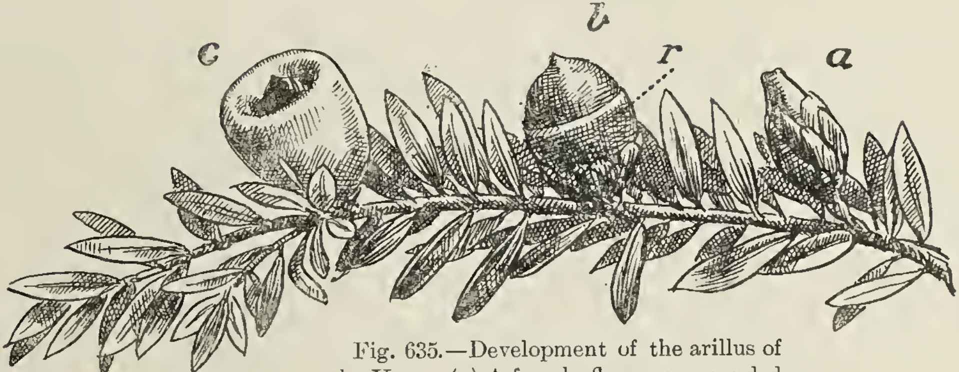


Fig. 635.—Development of the arillus of the Yew. (*a*) A female flower surrounded by scale-like bracts. (*b*) A female flower at a later stage, the arillus (*r*) growing up round the bud. (*c*) A ripe seed surrounded by fleshy arillus.

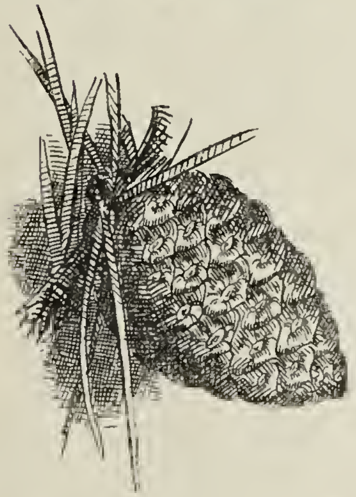


Fig. 637.—Cone of a Scots Pine.

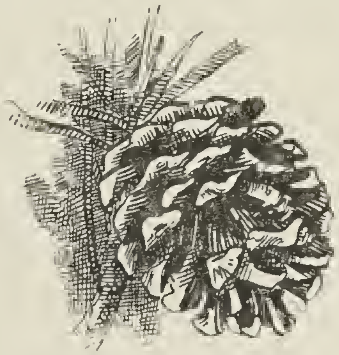


Fig. 638.—The same open.

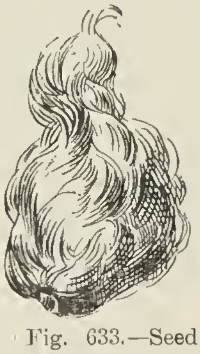


Fig. 633.—Seed of *Trigonia villosa*, a Brazilian climbing shrub covered with long woolly hairs.

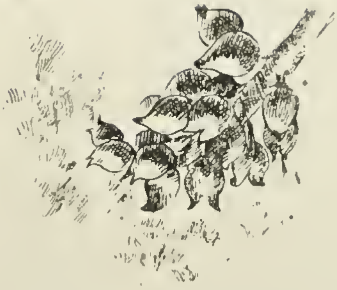


Fig. 641.—Part of catkin of Poplar. The seeds, furnished with long, silky hairs, are escaping from the capsules.

point of attachment to the placenta. This arillus is split into long silky hairs in the Willow (*Salix*); in the Nutmeg-tree (*Myristica moschata*) it consists of a dry flocculent coat (from which the mace of commerce is obtained); and in the Common Yew (*Taxus baccata*) it is succulent. The manner in which the aril of the Yew grows up around the seed is shown in figs. 635, 636. Winged seeds are common in the Gymnosperms, and are borne on scales, which are hence called *ovuliferous scales.* The Scots Pine (*Pinus sylvestris*, fig. 639) furnishes a ready example. On a dry breezy day the cones open with a crackling sound and set free the scales, which fly twirling through the air. The wing of the seed is an upper layer of the scale, from which it becomes detached when the seed is ripe. In the Hop Hornbean (*Ostrya carpinifolia*) the seeds are contained in inflated involucres, which hang in catkin-like clusters from the branch, and are readily borne about by the wind (figs. 642, 643).

The seeds of the Willow-herb (*Epilobium*) and some other plants are furnished with hairy coronets which assist dispersion; while those of the Poplar and Willow (*Populus*, fig. 641, and *Salix*) are provided with a silky fluff, which subserves the same purpose. Myriads of such seeds get stuck in the soft muddy banks of rivers, where they are sucked into the soil, and quickly germinate.

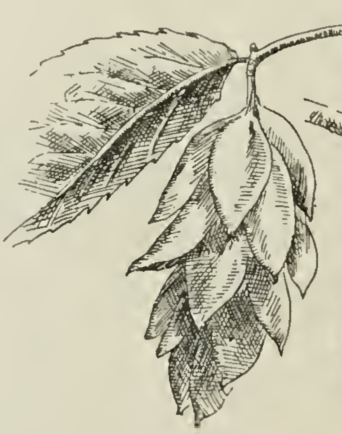


Fig. 642.—Hop Hornbean: female catkin.

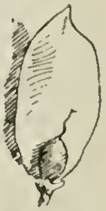


Fig. 643.—One of the inflated involucres opened to show the seed.

CHAPTER XIV

HIDDEN MARRIAGES

"'Twas a most secret marriage."
"I pray you tell me of it."
Old Play.

WE have already glanced briefly at the phenomenon of reproduction by spores, and cited examples from the principal groups of the Cryptogamia—the so-called Flowerless Plants—but these plants are so numerous, and they are divided into so many classes and orders, each with its own particular variation of the reproductive process, that a rather fuller treatment of this phase of their economy seems called for. Though none of them produces the petals and sepals which to the public eye constitute the sole claim to the title of flower, and though in some there is not the faintest approach to a sexual union, the term "flowerless" as applied to the entire division of these plants is somewhat inappropriate and misleading. In many of the groups the essential organs of Phanerogams are represented by *antherids* and *archegones*, and the female element has to be fertilised by the male before a true embryo can be formed.

Until recent years the term *spore* was made to do duty in this division as the name for bodies of widely differing values, and the result has been that much confusion is caused in the minds of students. Messrs. Bennett and Murray, in their *Handbook of Cryptogamic Botany*, have proceeded upon the more sensible plan of giving distinctive names to the body resulting from special methods of fertilisation, in harmony with those used for Phanerogams, restricting the use of *spore* to those propagative bodies that are produced without fertilisation. We shall adopt their terminology in the main here.

The vast majority of the Cryptogamic Plants are composed entirely of cellular tissue. Scalariform tracheides are the most frequent form of thickening in the *xylem*, and sieve-tubes occur commonly in the *phloem*, but true vessels formed by the union of cells are rare.

Respecting the diversity in the foliar organs of the Vascular Cryptogams, Messrs. Bennett and Murray have given a clear view of the principal types in a paragraph: "The size and form of the leaves are extremely various. In *Lycopodium*, *Selaginella*, and some other genera, they are very small, unsegmented, and lanceolate, not unlike those of mosses, and form a dense imbricated clothing to the stem; in *Psilotum* they are altogether rudimentary; in the Equisetaceæ they are reduced to divisions or teeth of a membranous sheath; in *Isoëtes* (Selaginellaceæ), *Pilularia* (Rhizocarpeæ), and *Phylloglossum* (Lycopodiaceæ) they are long, narrow, and awl-shaped.

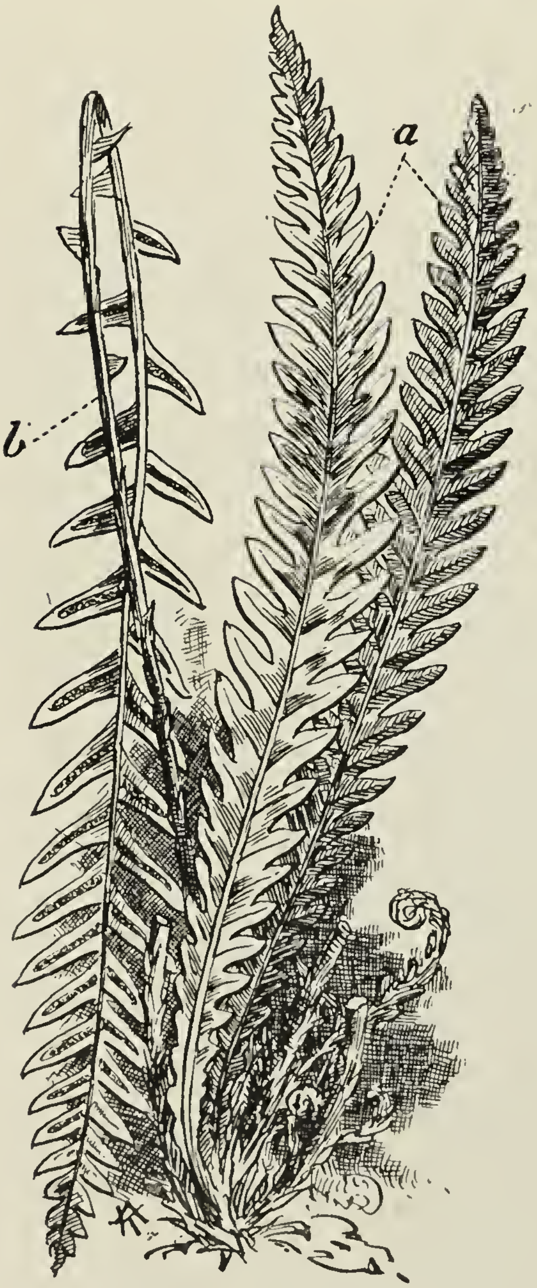


Fig. 644.—Hard Fern. (*a*) Barren fronds. (*b*) Fertile frond.

In some ferns the barren and fertile leaves differ from one another in appearance and especially in the degree of division of the lamina. In *Salvinia* they are of two kinds, one floating on the surface of the water and entire; the other submerged, very finely divided, and performing the functions of a root; in *Azolla* (Rhizocarpeæ) they are floating and bilobed. In some genera of Filices and their allies the leaves are quite entire; in the Hymenophylleæ they are very delicate, consisting of only a single layer of cells, and in the smaller species closely resemble those of the foliose Hepaticæ; while in most ferns they are of considerable (in the tree-ferns of gigantic) size, with well-marked petiole, rachis, and lamina, and distinguished by the great extent to which the lamina is divided. In most cases (except the Hymenophyllaceæ) they are abundantly provided with *stomates*. The tissue beneath the epiderm consists of a parenchymatous mesophyll containing abundance of chlorophyll, the portion of which adjacent to the upper epiderm is frequently developed as palisade-parenchyme. This mesophyll is permeated by 'vascular' bundles or veins, which branch off from the cauline bundles, and are distinguished in the majority of ferns by their dichotomous mode of branching, in contrast to the reticulate anastomosing in Dicotyledons, and the parallel arrangement in most Monocotyledons. Among Gymnosperms a similar arrangement is presented by *Salisburia* and *Stangeria*. The floral metamorphosis of the leaves of Flowering Plants does not occur in Vascular Cryptogams, nor their special agglomeration round the organs of reproduction as in Mosses."

The spore-case (*Sporange*) varies greatly in the different families, and is variously grouped, but there is more uniformity in the origin of the spore itself, which is produced much in the same way as the pollen-grain of Flowering Plants. A single cell, or group of cells, shows by the nature of its contents at an early period that it differs from the surrounding cellular tissue. It is known as the *archespore*, and from it is developed the *sporogenous tissue*, which divides and subdivides into the mother-cells from which the spores originate.

The Vascular Cryptogams (Pteridophyta) are divided into the following Classes and Orders :—

PTERIDOPHYTA.

Class I.	Filicinæ	Order 1.	Filices, or Ferns.
		„ 2.	Hydropterideæ, or Water-ferns.
„ II.	Equisetinæ	„ 3.	Equisetaceæ, or Horsetails
„ III.	Lycopodinæ	„ 4.	Lycopodiaceæ, or Club Mosses.
		„ 5.	Selaginellaceæ, or Selaginellas and Quillworts.

The Order Filices or Ferns is the best-known of all the Cryptogams, and most of its families have been well worked out. They are chiefly perennial herbs (very few annual), though some have shrubby stems or root-stocks, and the tree-ferns are arborescent. Their leaves, or fronds, may be simple, as in the case of the Common Hartstongue (*Scolopendrium vulgare—vide* p. 117), finely subdivided like those of the Bracken (*Pteris Aquilina*), or to any intermediate extent. The sporanges are borne in clusters (*sori*) of various kinds on the back or the margins of the frond, and are usually placed above a vascular bundle. The sorus is often protected by an *indusium*, which is an outgrowth from the epiderm and may be two-valved, cup-shaped, linear, hood-like, buckler-shaped, kidney-shaped, or a continuation of the frond margin. In some species the sori are produced on special fronds, which may differ in appearance from the barren fronds, as is the case with our Hard Fern (*Lomaria Spicant*, fig. 644) and Parsley Fern (*Cryptogramme crispa*).

In germination the exospore bursts and the contents by growth and division rapidly develop into a minute green heart-shaped scale (*prothallium*), with a depression of the anterior margin, in which the growing point is seated. The prothallium as a whole consists of a single layer of cells, but behind the growing point a cushion of several layers is formed, from one part of which root-hairs are produced. On a portion of the cushion clear of root-hairs the archegones will be found, and among the root-hairs or on the margins are the antherids. *Cystopteris fragilis* produces prothallia of two kinds, a smaller bearing antherids only, and a larger bearing both antherids and archegones. The prothallia of *Gymnogramme* bear antherids at first and archegones appear later (fig. 645). Each antherid contains comparatively few antherozoids, each being ribbon-shaped, coiled three or four times, with a number of fine cilia at the anterior end. The archegones have a curved neck with a canal leading to the oosphere. The canal is formed by the breaking up of a central row of cells whose walls and contents dissolve into mucilage, which is expelled and serves to retain the antherozoids, which then make their way into the canal, some of them reaching the oosphere and fertilising it. Only one archegone on a prothallium is fertilised; and on many prothallia no fertilisation takes place. In some varieties of *Asplenium Filix-fœmina* and *Aspidium angulare* prothallia bearing normal antherids and archegones are produced on the fronds. The phenomenon is known as *apospory* or suppression of the asexual generation. Certain species of *Asplenium* and *Cystopteris* produce buds on the fronds, which grow into little plants without any fertilisation (figs. 646-656).

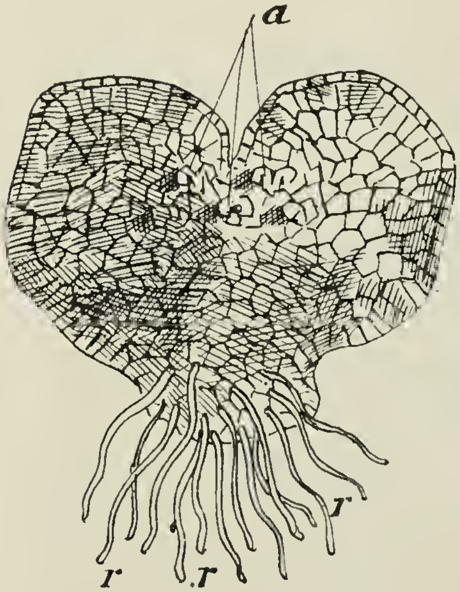
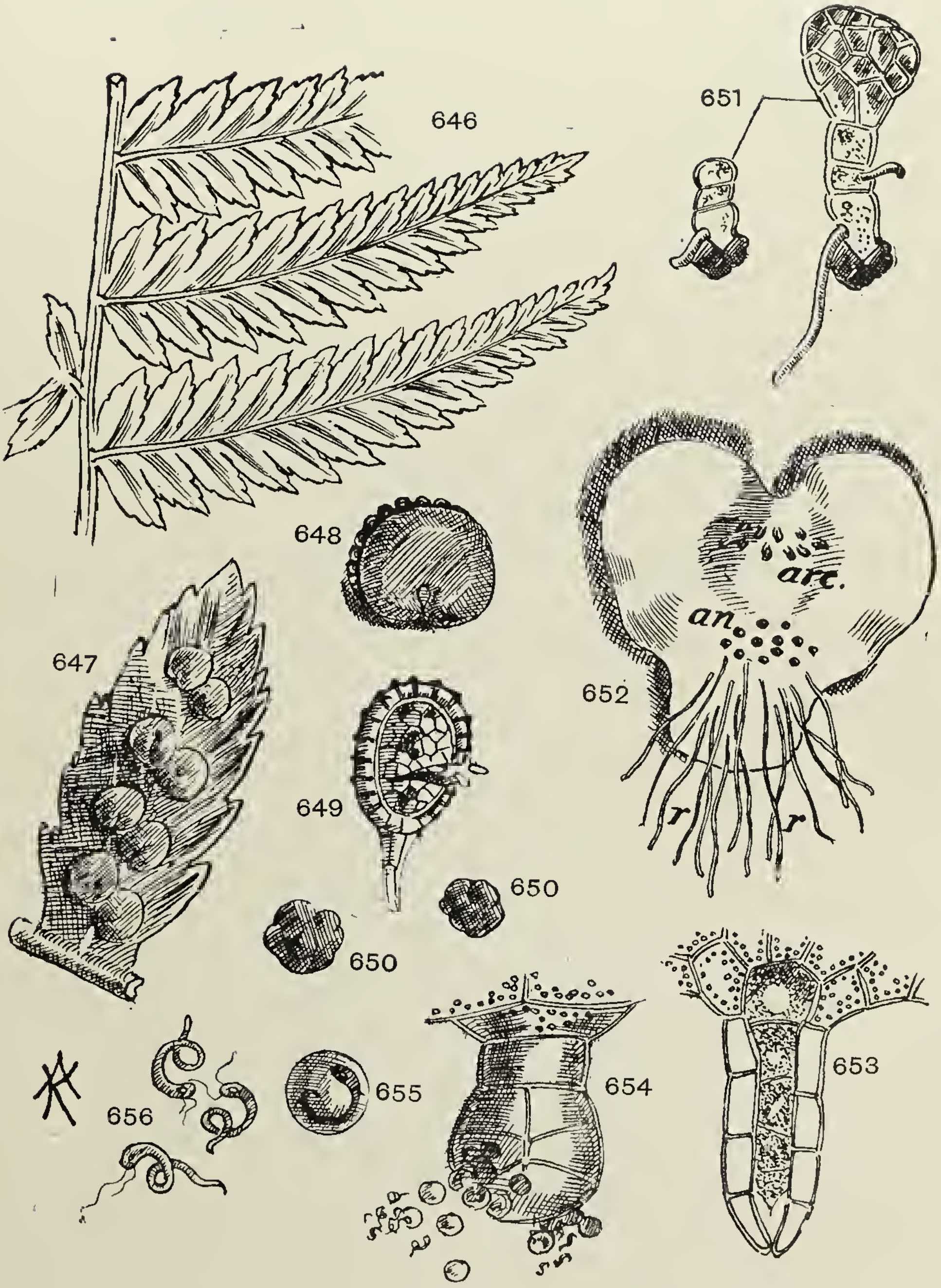


Fig. 645.—Prothallium of *Gymnogramme chrysophylla*, under side. (*a*) Archegonia, (*r*) Rootlets.

In Polypodiaceæ, which comprises most of our native genera, the sporanges have foot-stalks: in all or nearly all the other orders they are sessile. Each sporange has originated in a single cell of the epiderm. It is a round, oval, or pear-shaped capsule, and when mature the walls consist of a single layer of cells. A longitudinal row of these cells, known collectively as the *annulus*, have thickened borders. From two to four others, known as *lip-cells*, have lignified walls; it is between these lip-cells that the dehiscence or rupture of the sporange begins. This is brought about by the drying and consequent unequal contraction of the cells of the annulus, which pull the lip-cells apart; following their separation the sporange splits across and scatters the spores. The annulus does not form a complete ring in this order. Frequently from the foot-stalk of the sporange in Polypodiaceæ there is a hair-like outgrowth—a *paraphyse*. There are normally sixty-four



FIGS. 646-656.—LIFE HISTORY OF MALE SHIELD FERN (*Aspidium Filix-mas*).

Fig. 646.—Two pinnæ and portion of a third from frond. Fig. 647.—Fertile pinnule of a pinna (under side). The eight roundish bodies are the sori, or collection of sporangia; each sorus is covered by a peltate indusium. Fig. 648.—One of the sori. The sporangia are visible at the margin of the indusium. Fig. 649.—A sporange, with spores escaping through the opening. Fig. 650.—Spores, with warty projections. Fig. 651.—A germinating spore in two stages of growth. It gives rise to the prothallium. Fig. 652.—The prothallium (under side): (*arc*) archegonia; (*an*) antheridia; (*r r*) root-hairs. Fig. 653.—An archegonium. Fig. 654.—An antheridium; antherozoids escaping. Fig. 655.—Antherozoid in mother-cell. Fig. 656.—Antherozoids.

spores in each sporange of this order, produced in the usual way by division of the archespore into mother-cells and subdivision of each of these into four spores.

In the Family Hymenophylleæ (Filmy Ferns) there is usually a creeping stem, and the fronds are very thin and translucent, the mesophyll consisting of one layer of cells only. The indusium is cup-shaped (fig. 657). The fertile vein projects beyond the edge of the frond, and a prolongation of it called the *columel* extends into the centre of the indusium, where the sporanges are borne spirally upon it. Instead of being seated on a foot-stalk as in Polypodiaceæ, they are attached to the columel by one of the two convex faces. The annulus is complete. The spore undergoes division into three cells before the rupture of the exospore, two of which soon cease to develop, but the third increases greatly in length, divides transversely, and puts out thread-like lateral shoots, from which flat prothallia are produced. As will be seen later, this form of prothallium approximates with the *protoneme* of Mosses, and as the order contains the simplest of the ferns it may be that it marks a stage in their evolution from the Mosses. The antherids will be found about the middle of these filaments, the archegones at the extremity. The phenomenon of *apogamy*—the substitution of a vegetative for a sexual mode of reproduction—occurs frequently in this order, and it is thought may be quite usual in certain species. Little foot-stalks (*sterigmas*) produced from the prothallium bear bulbils of a few cells which slowly germinate and grow into sporophytes without any process of fertilisation. All the species in this order are of exceedingly delicate texture, and can only endure a moist warm atmosphere. The fronds are without stomata.

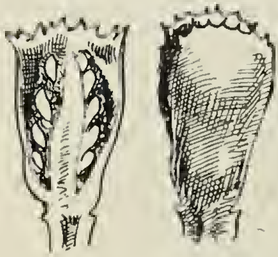
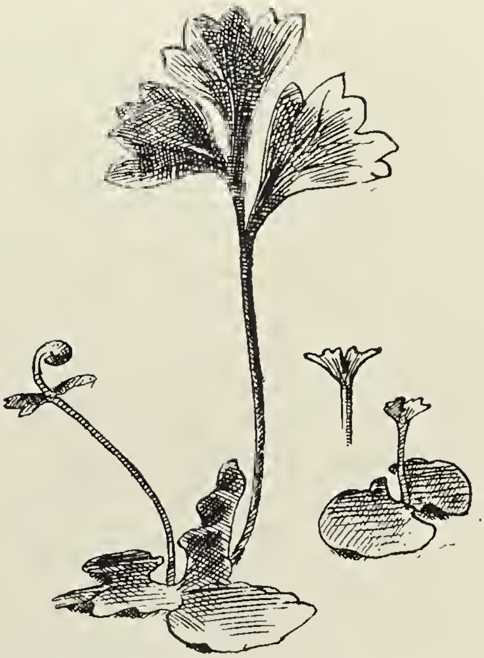


Fig. 657. — Cup-shaped indusium of a Filmy Fern (*Hymenophyllum*), whole and in section.

The Order Osmundaceæ is deficient in the indusium, and the annulus is very greatly modified. The sporanges are borne on certain of the pinnules of the fertile frond of which the mesophyll is partly or entirely undeveloped, so that only the sporanges thickly clustered round the midrib are visible. The sporange is not symmetrical; in some species it is shortly stalked, in others sessile. The incomplete contracted annulus is near the apex on one side, and at a little distance from this the sporange splits vertically. The prothallium exhibits a tendency to become diœcious; sometimes all the spores from one sporange produce prothallia that bear antherids only, or archegones only. Some prothallia bear antherids first and archegones later. Often the prothallium throws out adventitious shoots, and so propagates itself vegetatively. Murray and Bennett, following Goebel, describe the prothallia of *Osmunda* *regalis* as ribbon-shaped, but that does not agree with our own experience. We have always found that, beginning as a heart-shaped plate, the sinus deepens until the two lobes become widely separate, and by their growth in all directions a corresponding sinus is formed behind, so that they ultimately become dumbbell-shaped, as shown in the figure (fig. 658).



After Edward Step.

Fig. 658.—Successive stages of growth of Sporophyte in *Osmunda regalis.*

In all these orders of Ferns the vernation is *circinate*, the frond and its divisions being rolled up from the apex. The genera *Ophioglossum* and *Botrychium*, often included in the Class Filices, differ from them in this respect among other differences, their fronds in the incipient stage being folded from the sides. These genera are, therefore, elevated into a separate class, the Ophioglossaceæ. The upright stem produces only a few leathery fronds, often only one frond. The rachis of the frond is furnished at the base with scaly outgrowths, like the so-called stipules found in a tropical order of ferns, the Marattiaceæ. When the rachis has attained half its final length, it forks, one branch developing into a smooth leafy expansion, furnished with stomates on both surfaces, the other becoming the sporophyll bearing the closed sporanges. These fronds are of very slow growth; in our Moonwort (*Botrychium Lunaria*, fig. 659), for example, they do not appear above ground until four years after the formation of the bud, their expansion marking their fifth year. The root-stocks are poorly developed, bearing thick fleshy root-fibres without root-hairs; those of Adderstongue (*Ophioglossum vulgatum*—*vide* p. 117) put forth adventitious buds.

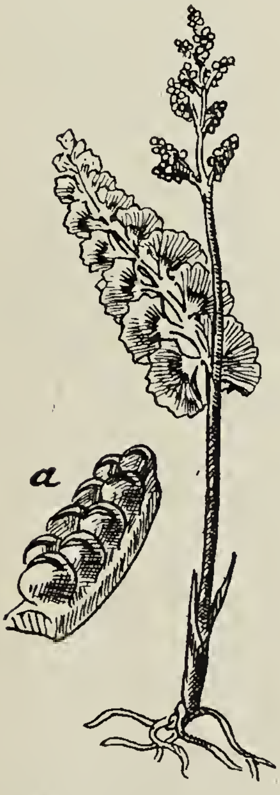


Fig. 659. — Moonwort. (*a*) Closed sporanges of same.

As we have seen, in the Polypodiaceæ each sporange is formed from a single cell of the epiderm;

but in the Ophioglossaceæ a single sporange is the product of a group of specialised cells beneath the epiderm, and is therefore more homologous to an entire sorus in the true ferns. Its walls, several cells thick, are products of the epiderm, and are still furnished with stomates. Their full development occupies a year, and they are then globose in shape, have no annulus, and split transversely to liberate the minute squarish spores. Instead of germinating on the surface as do the spores of ferns, these appear to need burial before developing into prothallia; at least, so far as it has been observed, the prothallium is a subterranean tuberous body, devoid of chlorophyll, and bearing archegones and antherids seated in pits or projections of the upper surface—the former in *Botrychium*, the latter in *Ophioglossum*. These organs and their contents are very similar to those of ferns.

The Order Hydropterideæ, or Water-ferns, is a small group consisting of few genera and species, with a solitary British representative, the Pillwort (*Pilularia globulifera*). They are aquatic plants, and the spore-cases (*sporocarps*) are borne at the base of the leaves. The Pillwort, which grows on the margins of lakes and ponds where it is submerged in winter and exposed in summer, consists of a creeping stem from the under side of which are produced at intervals small tufts of fibrous roots, and from the upper surface erect, cylindrical, bristle-like leaves, in whose axils are the short-stalked, globular sporocarps. These sporocarps, which have a hard shell of sclerenchyma, are divided into four compartments, and in each of these, springing from the broadest face of the wall, is a cushion analogous to the placenta in the ovary of Phanerogams, and to which are attached megasporanges containing one large spore, and microsporanges containing a large number of small spores. The sporanges attached to each placenta constitute a *sorus*. The megasporanges are chiefly the lower bodies of the sorus, and although at an early stage of development the contents of each becomes broken up into sixty-four cells, only one of these becomes mature and develops into a megaspore. Each microsporange, however, produces sixty-four microspores. The megaspore becomes invested, first, in a hard brown coat, but later this receives an outer gelatinous coat—the *epispore*—consisting of three layers,

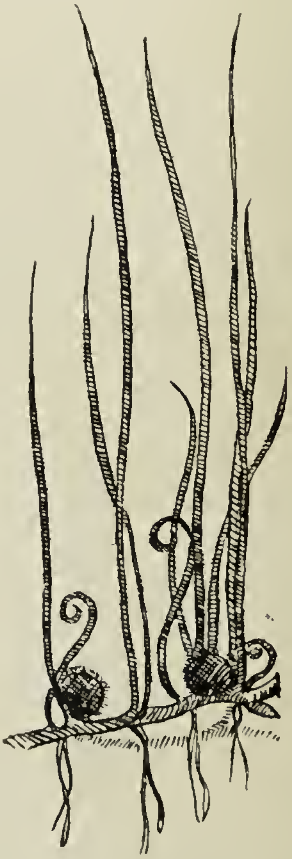


Fig. 660.—Pillwort: plant showing fruits at base of leaves.

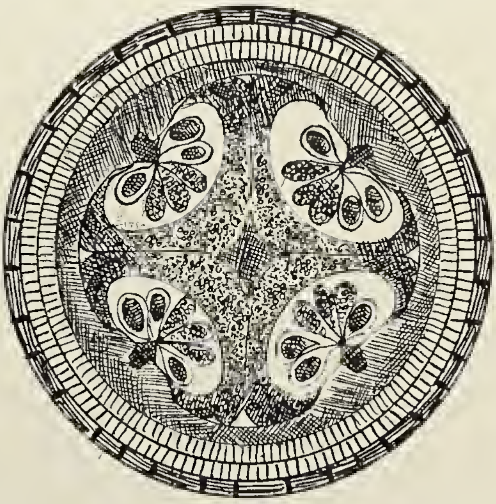


Fig. 661.—The same. Transverse section (diagrammatic) through one of the fruits. Clusters of megasporanges and microsporanges are seen in each of the four compartments.

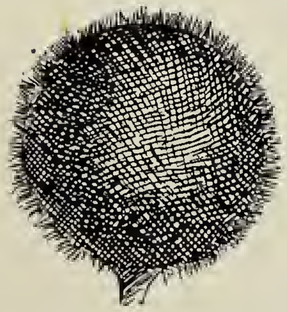


Fig. 662.—The same. One of the fruits entire.

except at the apex of the spore where the two outer layers are wanting, and the apex in consequence lies in a cavity whose walls are the two outer layers of the epispore. At the apex the protoplasm breaks up into several cells, which are not at first invested by cellulose, but finally form a tissue containing a little chlorophyll and developing into a *prothallium.* The growth of the latter causes it to break through the apical layers of the megaspore and project as a spherical body into the cavity previously referred to. In the centre of the prothallium there is a large cell (afterwards the *archegone*) covered by four other cells, from which arise the neck and stigmatic cells of the *archegone.* The greater portion of the protoplasm of the archegone contracts into an *oosphere* (figs. 660-663).

Each microspore divides into three cells, of which one becomes a sterile prothallium, but each of the other two divides into sixteen cells, and the nucleus of each of these becomes an *antherozoid*—a rod-like body coiled four or five times, to which are attached a few cilia, by whose vibration the body is impelled. The antherozoids find their way to the funnel above the apex of the megaspore, and getting entrance by the neck of the archegone, reach the *oosphere* and fertilise it. The result of this fertilisation is the development of the oosphere into an *oosperm*, which becomes invested with cellulose and undergoes segmentation to form the embryo with its root, stem, first leaf, and an attachment (foot) to the prothallium. Thus arises the *sporophyte* like that by which the sporocarps were produced. The "leaves" of Pilularia consist only of the petiole, no lamina being developed. In the early stages these leaves are coiled up from the apex to the base, and gradually unroll as they grow to their full size.

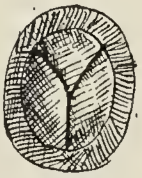


Fig. 663.—The same. A microspore.

Marsilea, which grows in similar situations to *Pilularia*, but does not occur in this country, has a quatrefoil leaf, the segments of which fold together towards night and expand again in the morning, thus agreeing in its sensitiveness to light with the leaves of *Oxalis* and other trefoils among Phanerogams.

The Class Equisetinæ, or Horsetails, consists of the Order Equisetaceæ and a single genus, *Equisetum*, of erect, hollow-stemmed, jointed, and leafless plants. The leaves are represented by the teeth of the sheath in which each node terminates. The branches, where present, are jointed, but, unlike the stem, are solid, and spring from the base of the sheath. The stems are ridged and grooved longitudinally, each species having a characteristic number and form of ridges, and the sheath-teeth correspond with them. In some species there are barren and fertile stems, the latter being without branches and almost or entirely devoid of chlorophyll. Silica is deposited abundantly in the cell-walls of the cuticle, and in consequence several species have long been used under the name of Dutch Rushes for scouring and polishing metal. Stems and branches alike are provided with stomates and chlorophyll, and can carry on the functions of the absent leaves.

The fertile stems bear at their extremity a cone-like spike of sporange-bearing discs. These discs or scales are the sporophylls; they are many-sided (usually hexagonal), supported on a central foot-stalk, and bear on the under side from five to ten sporanges. The sporophylls are arranged in whorls corresponding with the sheaths, and probably, like them, modified leaves. Between the uppermost developed sheath and the lowest whorl of sporophylls there is an undeveloped sheath forming an involucre to the fruit-spike. The sporange has no annulus, and opens by a longitudinal fissure to set free the spherical spores, which differ from those of ferns in having four coats, the outer of which splits up spirally into four strips with broader ends, known as *elaters* (fig. 664). These elaters are highly hygroscopic, and as they dry they stretch out from the spore; but on the air becoming moist, they contract, and twist around the spore. If a slide of these spores be breathed upon and then viewed through the microscope, they will be seen to leap about as they dry. Another difference between these and fern-spores is found in their possession of chlorophyll. Fern-spores are devoid of this important substance, and if kept dry will retain their vitality, in some species, for several years; but chlorophyll will not keep, and unless the spores of Equisetaceæ are placed under such conditions as to induce germination, they perish within a few days of their dispersion. If the proper conditions are present, germination is very rapid—a matter of a few hours only.

The prothallia are commonly diœcious—that is, the archegones are borne on a different prothallium from that which bears the antherids, but a few organs of the opposite sex are often produced at a later date. They are very much longer than broad, and the newest portion is much broader than the old. The less vigorous prothallia are male, the more vigorous female; both are lobed at their anterior margin, but the lobes of the females are long strap-shaped extensions. Both forms are found in close proximity, so that the antherozoids can easily pass to the archegones by the aid of the moisture that condenses upon the prothallium. The sexual organs and their contents are very similar to those of the ferns. After fertilisation of the oosperm and formation of the embryo, minute stems are produced, differing in little except stature from the mature stems, and an underground perennial rhizome is also developed. In some species there is a vegetative propagation by the formation of tubers on the rhizome and the bases of the stems, in which starch, etc., is stored.

The Class Lycopodinæ consists of the Orders Lycopodiaceæ and Selaginellaceæ. In the former the typical genus *Lycopodium* is represented in Britain by five species of Club Mosses, so-called because in some species the sporophylls are crowded together on special erect branches which, from being stouter than the stem immediately below them, have a clavate appearance. There is usually a rigid stem with overlapping small undivided leaves, which either invest the stem all round or are arranged in from two to six rows. Some exotic species have erect stems, and of these certain tropical ones are stout and shrubby. Several have even become climbers, and a few have given up their connection with the earth and grow only upon trees (*epiphytic*). The kidney-shaped sporange is attached by a short stout foot-stalk to the base of the sporophyll. It is one-celled, and splits when ripe into two valves. The numerous spores are more or less rounded, marked with three radiating lines on the upper side,

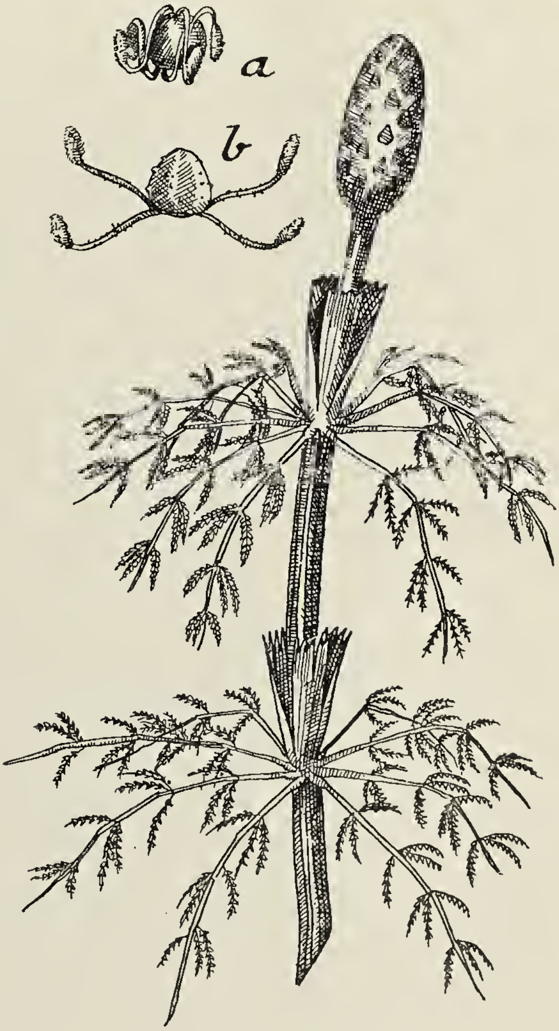


Fig 664.—Sylvan Horsetail (*Equisetum sylvaticum*). (*a*) A spore, highly magnified, with the elaters coiled round it. (*b*) The same with the elaters unrolled.

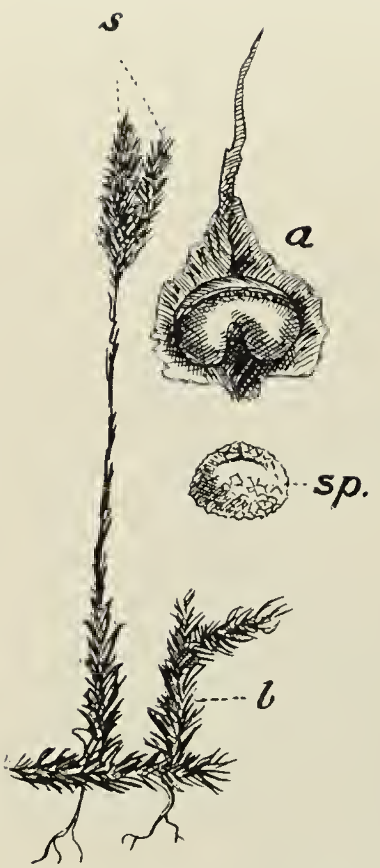


Fig. 665.—Common Club Moss (*Lycopodium clavatum*). (*s*) Spikes. (*b*) Branch. (*a*) Fertile leaf with sporange. (*sp*) Spore.

and on germinating, the exospore splits along these lines into three valves, from which the endospore projects and grows into the germinating filament. A transverse wall (*septum*) develops across the filament and divides it into a small basal cell and a larger apical cell. No further change occurs in the basal cell, but the apical one divides into two series of cells, and each of these cells afterwards divides into two. Each cell is provided with a few grains of chlorophyll, except in *Lycopodium annotinum*, whose prothallium, being buried, is destitute of chlorophyll, and yellowish white in colour. Archegones and antherids are produced in close proximity upon the upper side of the prothallium. The antherozoids are minute, consisting of only a few coils and, so far as at present observed, a couple of cilia. Apparently only one archegone is fertilised on each prothallium. Very little is known of the early stages of growth in the sporophyte (fig 665).

The Order Selaginellaceæ consists of the two genera *Selaginella* and *Isoëtes*, both of which are represented by British species. Both megaspores and microspores are produced, but in a manner different from those of the Water-ferns, and the prothallium is quite devoid of chlorophyll. Our only native species of *Selaginella* is the Lesser Alpine Club Moss (*Selaginella selaginoides*), a small moss-like plant inhabiting bogs and marshes. Several of the numerous exotic species are well known in our conservatories and greenhouses. *S. selaginoides* has creeping stems only a few inches long and completely clothed all round with overlapping lance-shaped leaves. A few branches are of more erect growth, and the leaves of these are longer, more closely pressed to the stem, which ends in a stouter scaly cone about an inch long. This cone is the part of the plant that bears the sporangia, and the leaf-like scales containing them are known as *sporophylls*. The sporange, on a short stalk, springs from the stem just above the base of the sporophyll. Those in the lower sporophylls are spherical and megasporanges; in the upper sporophylls, flattened microsporanges (fig. 666). Each megasporange contains only three or four megaspores, which are set free by the splitting of the sporange into three or four valves; the microsporanges are only two-valved, and their contents are minute and numerous. Both kinds of spores are invested by three coats—*endospore*, *exospore*, and *epispore*. The growth of the prothallium within the apical portion of the megaspore proceeds *pari passu* with the development of the larger body, whilst the protoplasm which fills the greater portion of the spore is being converted into a cellular tissue variously designated the *secondary prothallium* and *endosperm*. The archegones are produced on the surface of the prothallium, some of them being already present when the latter is extruded from the megaspore. There is a neck with its canal leading to the interior with its oosphere. The microspores are coloured red or orange, and although development begins in the sporangia throughout the winter, they appear to make no advance upon their condition when set free. In spring, however, fresh activity is manifested, and one portion of the protoplasm becomes an antherid, some of whose numerous cells contain coiled antherozoids with two long cilia attached to the tapering fore-part. For half an hour or so after the rupture of the mother-cells the antherozoids are endowed with motion, and find their way by the neck canal to the oosphere. Thus fertilised, the oosphere develops into an embryo with a pair of primary leaves, a root, and a foot or organ of absorption.

The genus *Isoëtes* is represented in this country by a single species, the Quillwort (*Isoëtes lacustris*). Though the plants of Quillwort and Selaginella are as unlike as possible, the developmental history of the embryo is very similar to what we have just described. The Quillwort grows at the bottom of lakes, and its stem takes the form of a corm whose increase is not so much in length as in diameter. The leaves are awl-shaped, with broad overlapping bases which entirely hide the corm and in which the sporanges are produced. The outer leaves bear megasporanges, the inner ones microsporanges (fig. 667). A second species, *I. hystrix*, found in Guernsey, is of terrestrial habit, growing on sandy soil which is only occasionally inundated. In this Order the prothallium is not nearly so precocious as in *Selaginella*. The megasporange decays and sets free the megaspore, and it is not until several weeks later that the contents become converted into cellular tissue. Then the episporc breaks up by a three-rayed fissure at its apex, and the rupture of the endospore follows, exposing part of the prothallium, which is in this case spherical. An archegone appears at its apex, very similar to that of Selaginella, and if this becomes fertilised no other is produced; but

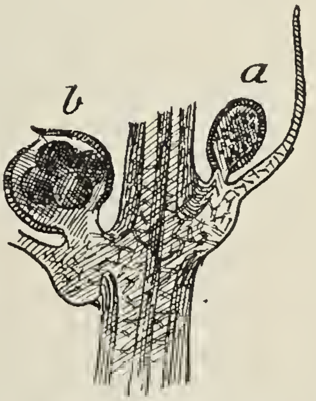


Fig. 666.—Sporanges of Lesser Alpine Club Moss. (*a*) Microsporange. (*b*) Megasporange.

in the event of failure, others appear until fertilisation of one is effected. The microspores are three-sided and ultimately contain long, slender, and spirally coiled antherozoids, which taper to a fine point at each end, where numerous cilia of great length are produced. The swarming period is only a matter of a few minutes, the antherozoids finding their way to the oosphere by the neck canal as in Selaginella.

We now come to those Cryptogams in which the structure is entirely cellular, the first division of which is the

BRYOPHYTA.

Class I. Musci. Mosses.
„ II. Hepaticæ. Liverworts and Scale Mosses.

In these classes we find an alternation of generations, as in the Pteridophyta, but there is a difference to be explained. Beginning with the spore, we find it to consist of a central mass of protoplasm, in which are chlorophyll-grains, etc., invested by an inner coat or endospore, and an outer coat, or exospore. On germinating, the endospore and its contents burst through the exospore and develop into a hair-like body—the *protoneme.* Side shoots from the protoneme develop into chlorophyllous scales in the Liverworts, and into leafy stems in the Mosses. These in turn bear sexual organs—archegones and antherids (*vide* figs. 119-124).

In the protoneme of the Mosses cell-division takes place in one direction only—transversely; but as this may go on indefinitely, we have the filamentous form. Some of the cells thus formed send out lateral shoots which in turn divide transversely, so that the protoneme may be ultimately many-branched. Distinct buds are also produced which develop into wiry stems, which are clothed with two, three, or four rows of leaves. The protoneme and this leafy plant produced by it must be considered as together constituting the oophyte or sexual generation. The leaves of Mosses are never stalked, and with the exception of a line down the centre and of the margins, consist of a single layer of cells; stomates being therefore unnecessary, they have none; but the stem is often liberally provided with stomates. Around the three-sided apex of the stem the leaves are more densely crowded, and these are more or less modified. They constitute

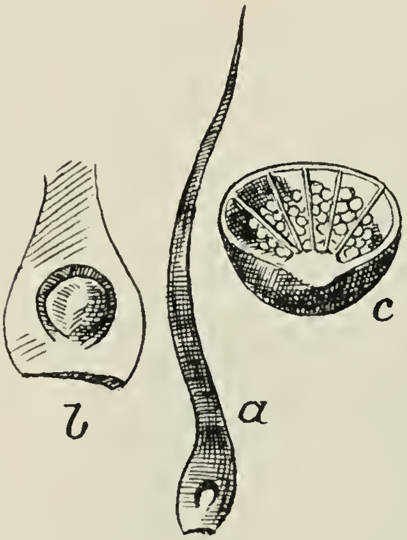


Fig. 667.—Fruiting arrangement in Quillwort. (*a*) Leaf with sporange. (*b*) Base of leaf, to show sporange on larger scale. (*c*) Transverse section through ripe sporange.

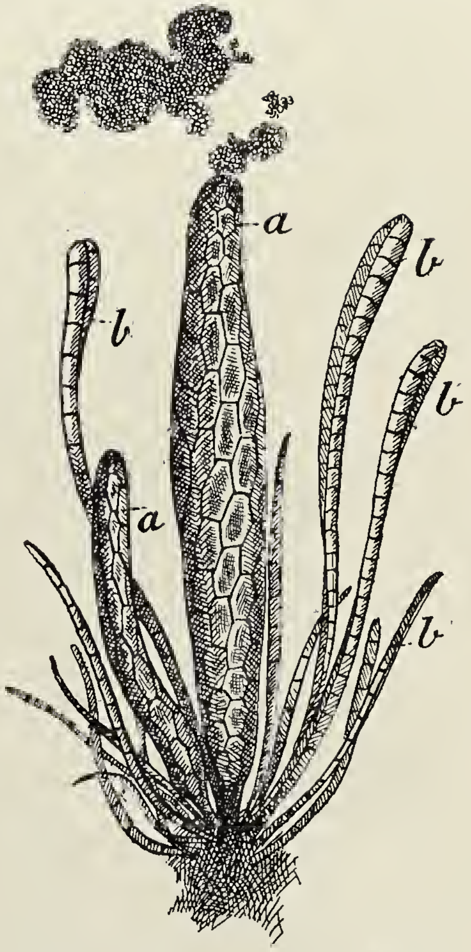


Fig. 668.—Hair Moss (*Polytrichum commune*). (*a a*) Antheridia. (*b b*) Hairs and sterile filaments (paraphyses).

the perichæte, popularly but incorrectly known as the "flower" of the Moss (fig. 668). These "flowers" are of three kinds: first, containing antherids only; second, containing archegones only; and third, containing both antherids and archegones. The male flower (*perigone*) may be distinguished by its broader and thicker leaves. Among the sexual organs are a number of thread-like or club-shaped bodies known as paraphyses. The antherid when mature consists of a foot-stalk bearing a club-shaped (sometimes spherical) head, which opens at the apex or splits down the sides, freeing a large number of minute cells, in each of which is coiled a long antherozoid, tapering forwards, at which extremity it is provided with two long cilia (cf. fig. 120). The antherozoids swim about in the mucilaginous fluid which accompanies their expulsion and make their way to the archegones. The latter consist of a swollen basal portion, in which is the oosphere, and a long, slender neck, pierced by a canal, the mouth of which is guarded until maturity by a couple of lid-cells (the *stigma*). At maturity, a quantity of mucilage being ejected from the canal, the lid-cells are forced apart, and the way is open for the entrance of the antherozoids. As a rule, only one oosphere in a flower is fertilised and becomes an oosperm. This develops into the sporogone or asexual generation, which, until it perishes, always remains attached to the sexual generation and is nourished by it. The growth of the sporogone ruptures the archegone transversely and stands revealed as the stalked capsule of the Moss containing the spores. The remains of the ruptured archegone become the *vagine* or sheath below the capsule, and the *calypter* or cap above it.

When the sporange is freed from the vagine and the calypter, we can see that it has a distinct lid or *opercule*, which is thrown off to allow the escape of the spores. When this is lifted off, the sporange will be found to have either a smooth rim around its mouth (*gymnostomous*), or it bears a *peristome*—a single or double series of slender appendages, the inner row being cilia, the outer row teeth, whose number is always some multiple of four. The peristome is hygroscopic. When the atmosphere is dry, the teeth or cilia stand away from the mouth and allow the dispersion of the spores; in damp weather they close the orifice and keep the spores dry. In *Polytrichum*, in which the teeth are short, there is another piece of mechanism to the same end. Beneath the opercule the mouth of the sporange is closed by an *epiphragm* supported on a central pillar, the *columel*, which rises from the base of the sporange. The wall of the sporange contracting in dry weather brings the epiphragm half-way up the peristome, thus allowing the spores to sift out between the teeth. In damp weather, with the elongation of the sporange, the epiphragm again comes to the base of the peristome and the orifices are closed. In the Order Phascaceæ the sporange does not dehisce at all, and the spores are only liberated by the decay of the walls. In Andreaceæ, again, there is no opercule, but four or eight slits appear in the sporange wall, from below the summit to near the base.

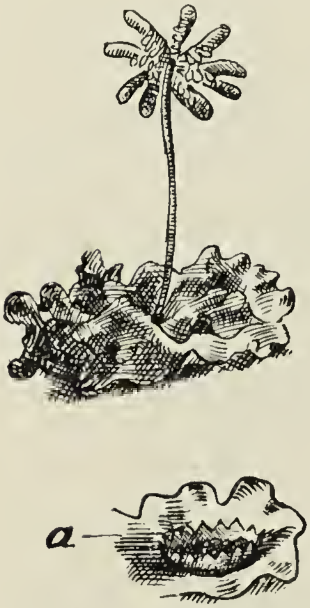


Fig. 669.—Female thallus of *Marchantia polymorpha*, with archegonial receptacle. (*a*) Cup-shaped receptacle of same containing *gemmæ*.

In the Liverworts and Scale Mosses we find two distinct types—a more or less flat green scale like a large fern prothallium, and a delicate plant with a well-marked differentiation into stem and leaves. Species that conform to the first type are known as Thalloid Hepatics; such as answer the second description are Foliose Hepatics. Both forms are entirely cellular, and are attached to the soil by root-hairs. The process of reproduction is similar to what we have seen in the Mosses, in that the spore gives rise to a protoneme from which the sexual generation is developed. The mode of bearing the sexual organs differs in various orders and genera. They may be produced from the growing point of the main stem or branches of the Foliose forms; in the substance or on the upper surface of the Thalloid forms, and in Marchantiaceæ on a special stalked outgrowth of the thallus, and known as the antheridiophore or the archegoniophore, according to sex (figs. 669-671). Both organs may be produced by one plant (*monœcious*), or they may be on separate plants (*diœcious*). These sexual organs originate in little swellings, which afterwards are seated each on its own little foot-stalk. The antherid splits irregularly and sets free a number of cells, each containing a spirally coiled, ciliated antherozoid. The archegone has an enlarged lower portion containing the oosphere, and an upper neck with its canal, through which the antherozoids gain access to the oosphere. After fertilisation the oosphere develops into the sporogone, usually elevated on its stalk, which carries it up through the calypter; this is the entire non-sexual generation. In *Riccia* the sporogone is immersed in the thallus. Among the spores are long attenuated cellular bodies, the *elaters*, whose walls are furnished with spirally twisted threads, which are hygrometric and cause the twisting of the elaters as they absorb or part with moisture. Their movements under this influence assist in the dispersal of the spores. The spores may be invested in one, two, or three coats, but usually two.

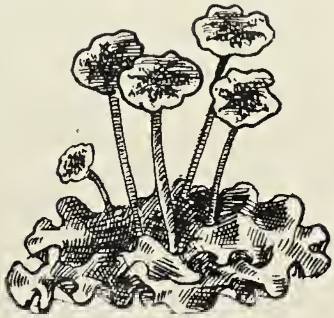


Fig. 670.—Male thallus of *Marchantia polymorpha* with antheridial receptacles.

The remaining classes of Cellular Cryptogams are grouped under the divisional name of

THALLOPHYTA.

Class I. Hyphomycetes. Fungi.
„ II. Characeæ. Stoneworts.
„ III. Rhodophyceæ. Red Algæ.
„ IV. Phæophyceæ. Brown Algæ.
„ V. Chlorophyceæ. Green Algæ.

Class VI. Conjugatæ. Conjugates.
„ VII. Peridineæ. Dinoflagellates.
„ VIII. Diatomeæ. Diatoms.
„ IX. Schizophyta. Fission Plants.
„ X. Myxomycetes. Slime Fungi.

The plants of the first class, the Fungi, are characterised by a total absence of chlorophyll and starch. Two distinct portions of a fungus are recognised, the vegetative or *mycele*, and the reproductive or *sporophore*. That to which we apply the term "mushroom" is the sporophore; the mycele consists of a network of white threads ramifying in the vegetable humus below. Fungi have no roots, properly speaking, though the mycele fulfils their office, both as absorbers of nutriment and for purposes of attachment. As they possess no chlorophyll, they are unable to decompose carbon dioxide, and therefore have to obtain their carbon in an already organised condition. This they get from dead or decaying plants and animals or from organic products, or by attacking living organisms. Species that perform the latter operation are classed as *parasites*; those that content themselves with organic remains are *saprophytes*. Members of either class that

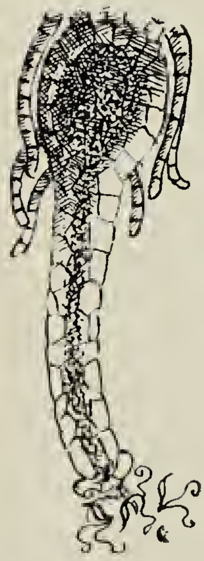


Fig. 671. — An archegonium of *Marchantia polymorpha*.

have the power during the whole or part of their life of performing the functions of the other class are qualified as *facultative* saprophytes or parasites, as the case may be. Another class live symbiotically with algæ, and are known as *lichen-forming fungi*—Lichens, formerly considered as a distinct subdivision of Cryptogams, being now known as compounds of fungal and algal elements (figs. 672-674).

The methods of spore-bearing differ greatly, but the spores are mostly formed non-sexually by a cell dividing transversely, the dividing portion rounding and dropping off as a spore. In the moulds (Oomycetes, Zygomycetes, etc.) they are formed singly or in chains, terminating branches. They may be formed by a division of the protoplasmic contents within a mother-cell, which thus becomes a sporange, the spores being liberated by the rupture or disappearance of the sporange-wall. These spores may be motile (zoospores) by the activity of cilia, as in *Saprolegnia* and *Peronospora* (fig. 675), or non-motile, as in *Mucor* (fig. 676) and the great majority of the Ascomycetes.

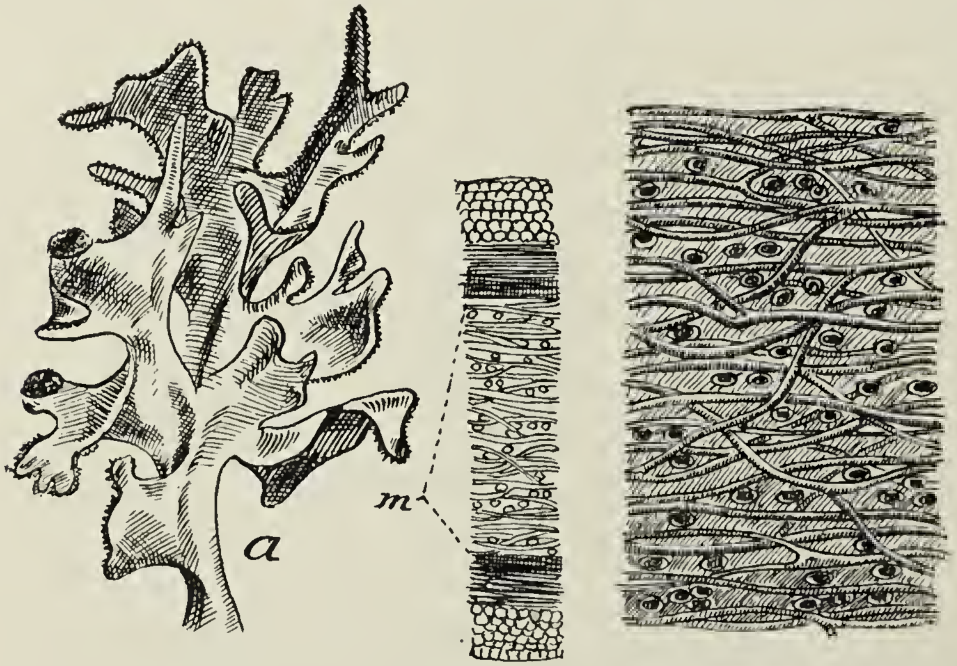


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Fig. 672.—Iceland Moss (*Cetraria islandica*), a lichen-forming fungus. (*a*) A thallus (the "Moss-plant"). Fig. 673.—Vertical section of same. The loose layer of mycelial filaments or *hyphæ* enclosed between the dotted lines (*m*) constitutes the gonidial layer. In the meshes of these *hyphæ* numerous small green unicellular algæ, of round or oval shape, are entangled. They are preyed upon by the *hyphæ* of the fungus, from which, however, they receive benefits in return. Fig. 674.—Greatly enlarged section of the gonidial layer.

These spores germinate under favourable conditions by pushing out

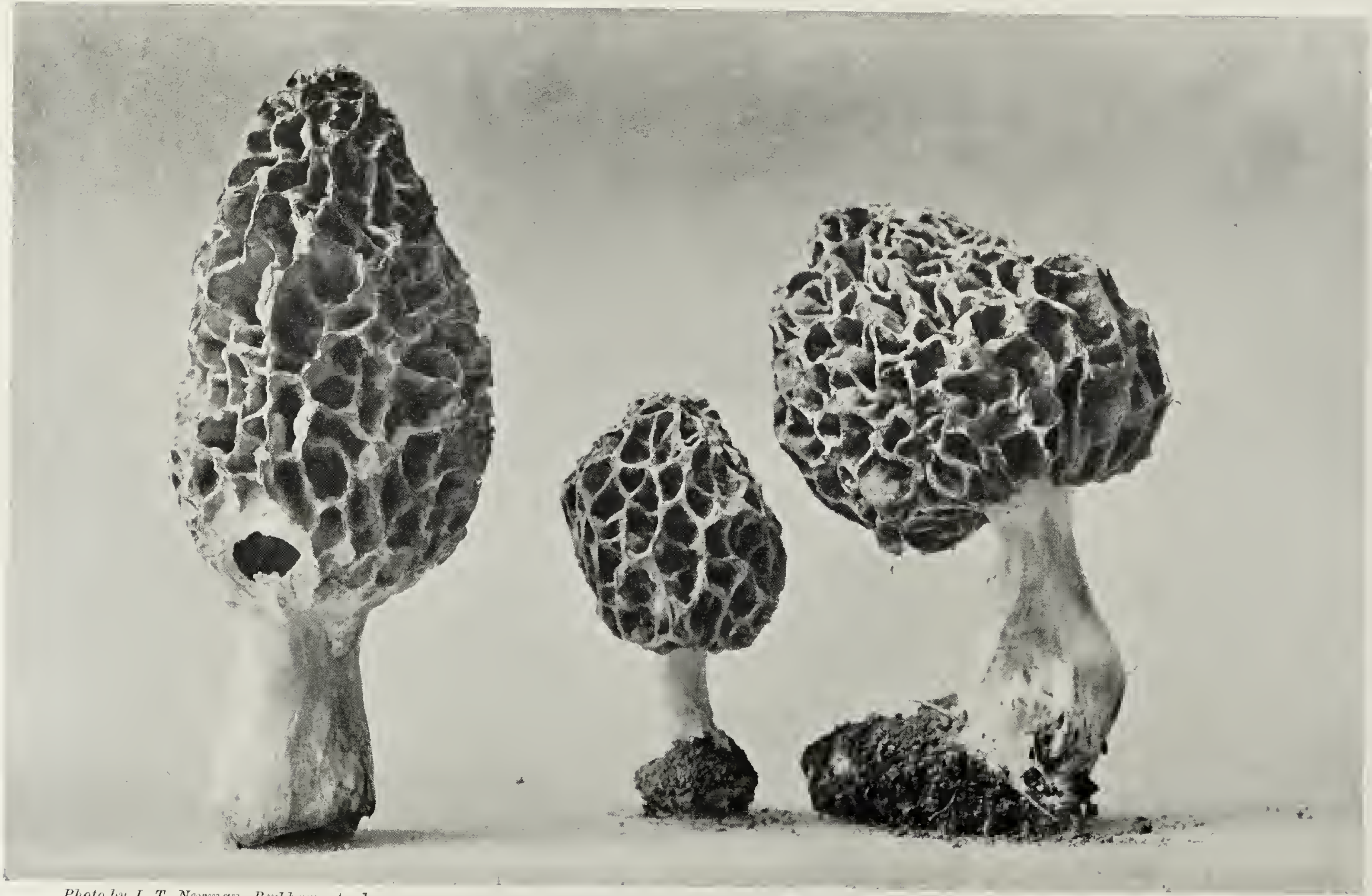


Photo by J. T. Newman, Berkhampstead.

MOREL (*Morchella esculenta*).

The spores are contained in small bladders (*asci*) in the external parts of the head, which, as seen in the specimens illustrated, are irregularly folded and much wrinkled These Fungi are edible.

PLATE XXXV.

germ-tubes which lengthen and branch until they form a new myccle. Moist and thin-walled spores that do not soon find the conditions favourable to germination perish; but many dry spores, if kept dry, retain their vitality for very long periods, and some of these (resting-spores) will not germinate until after some definite period from the time they were formed.

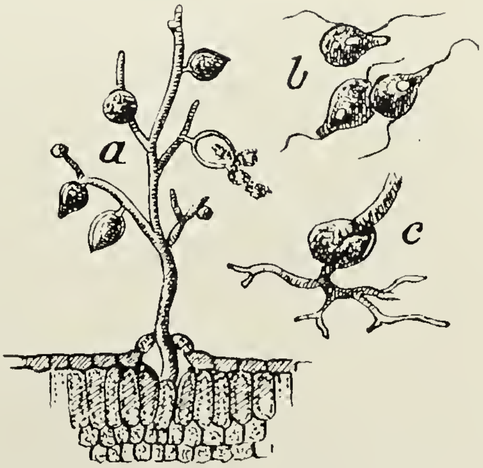


Fig. 675.—Potato-blight (*Phytophthora infestans*), one of the Peronosporæ. At *a* the hypha is shown growing out through a stomate of Potato leaf, and bearing sporanges, one of which is in the act of bursting. (*b*) Zoospores of the same. (*c*) A germinating zoospore.

In some groups there is no sexual generation, or at least such has not yet been discovered. This is the case, among others, of the larger Fungi, the Basidiomycetes, which includes the Mushrooms. Where it occurs it chiefly follows one of two methods. In Peronospora, Achlya, and possibly some Uredineæ, an oosphere is fertilised by the intrusion of an antheridial tube from an antherid formed on the same or a neighbouring branch. In Zygomycetes two special cells, presenting no apparent differences, come together by their apices and become firmly united. The apical portion of each (*gamete*) is then cut off by a transverse wall, and the division between the gametes gradually disappears, and the contents of both conjugate, the united mass growing into a *zygosperm*.

In the well-known Mushrooms (Hymenomycetes) the spore-bearing surface (*hymenium*) is spread over thin vertical plates (gills) radiating from the stem, or lines minute tubes (*Polyporus*). In the Puff-balls (*Lycoperdon*) and Earth-stars (*Geaster*, figs. 677, 678) the hymenium is internally invested by a double peridium, which splits at the summit and sets free the fine snuff-like spores. The outer peridium of *Geaster* is distinct and persistent; it splits into several lobes, which fall back and give the plant the stellate appearance to which its popular name is due. Figs. 677, 678 show *Geaster hygrometricus* in its first adult condition, and after the outer peridium has turned back. This action has the effect of detaching the sporophore from the

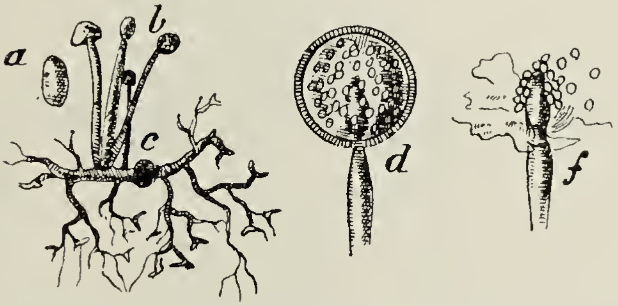


Fig. 676.—Common Brown Mould (*Mucor Mucedo*). (*a*, *c*) Gonidium from which the plant develops. (*b*) Sporangia. (*d*) Enlarged view of a ripe sporange. (*f*) The same, bursting to release the gonidia.

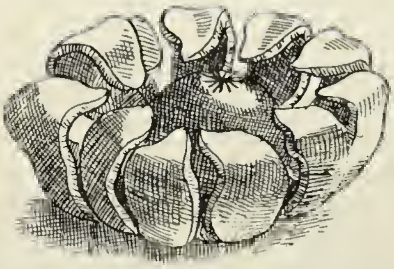


Fig. 677.—*Geaster hygrometricus*, one of the Earth-star fungi.

soil and thus assisting in the wider dissemination of the spores.

The Class Characeæ, or Stoneworts, consists of only two genera, *Chara* and *Nitella*. They are delicate water-plants which have a superficial similarity of form to the Horsetails; that is, there is a main stem with whorls of leaves, and branches of similar structure to the main stems. The leaves spring from distinct nodes, as in the Equisetaceæ, and the branches from the axils of some of the leaves, where also are found the sexual organs. The entire internode consists of one very large cell, in *Chara* invested by a *cortex* consisting of long slender cells arranged spirally, but in *Nitella* there is no such cortex, and the internodal cell stands absolutely naked. Long tubular cells grow downwards and serve as roots to fix the plant in the soil. In the clear internodal cells of these plants may be observed the phenomenon known as *cyclosis*, or rotation of the protoplasm along well-defined routes up one side of the cell and down the other, the two currents being separated by clear bands devoid of chlorophyll. In the axils of the leaves will be seen two kinds of bodies, some round and orange-red, the others elliptical and apparently green. The red bodies are antherids, the green are oogones. These oogones under the microscope are really orange, but the colour being masked by surrounding green bracteoles, they appear green to the naked eye. Some plants produce organs of one kind only; in others the two kinds are found close together. Both organs are supported on a short stalk consisting of the pedicel-cell (fig. 679).

The walls of the antherid are composed of eight flat cells, and from the centre of each on the inner surface a cylindrical cell—the *manubrium*—is attached, and extends towards the centre of the antherid, where it supports a rounded cell, the *capitulum*. Each capitulum in turn supports six *secondary capitula* of smaller size, and each of these bears four coiled filaments, which are divided into a large number of flat cells, and in each of these is a spirally coiled antherozoid, like those of the Mosses, with a couple of long cilia at the anterior extremity. When these are ripe, the

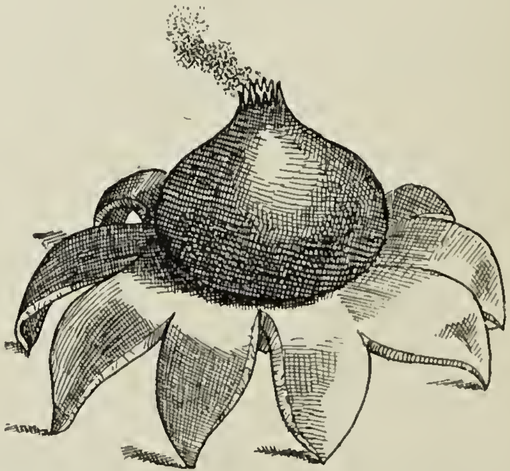


Fig. 678.—The same, with its peridium expanded by moisture; the spores are escaping as a cloud of dust.

antherid falls apart and the antherozoids move through the water by lashing their cilia. One antherid contains an average of thirty thousand antherozoids. The red colour is due to the inner face of the wall-cells being lined with chlorophyll-grains, which turn red as the antherid develops.

The walls of the oogone consist of long twisted cells, the whole surmounted by a crown of five or ten smaller cells, which ultimately separate and form a neck with a central cavity leading to the interior. Here there is a large central germ-cell (*oosphere*) with a receptive spot at its apex, which becomes liquefied and so allows entrance to the antherozoids when they have passed the narrow passage of the neck. After fertilisation the outer coats of the oosperm harden into a black pericarp, and later the entire fruit falls off the plant to the bottom of the pond, where it remains inactive till the following spring, when germination takes place. At this period the oosperm has divided into one large and two small cells, the first apparently serving as a reserve of nutriment, whilst from one of the smaller cells a primary root is developed, and from the other the proembryo—a long filament composed of a single row of cells. Across this a primary node is formed, from which arises a whorl of rhizoids, and beyond the node a very long internode; then another node, from which arises a cluster of leaves, amid which a bud is formed, and from this the new plant takes its origin. The proembryo is continued to a great length beyond the second node. It will be

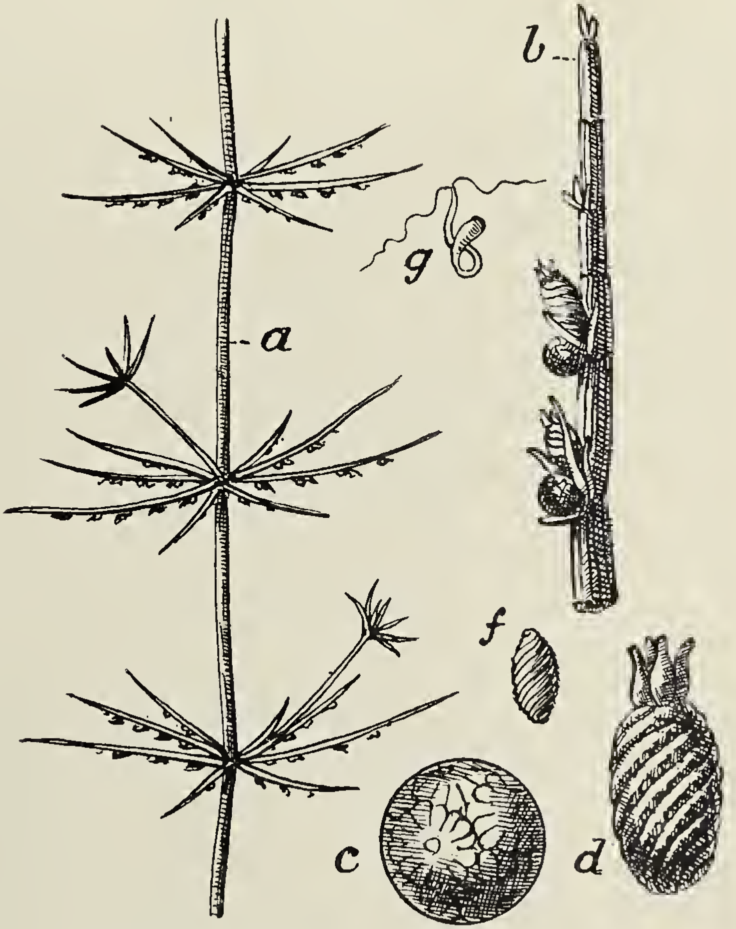


Fig. 679.—Stonewort (*Chara*). (*a*) Portion of the plant in fruit. (*b*) A fertile leaf with spherical antheridia and spirally walled archegonia. (*c*) An antheridium. (*d*) An archegonium. (*f*) A spore. (*g*) An antherozoid.

seen that in the entire life-cycle of the Characeæ there is no sporophyte, so there is no true alternation of generations.

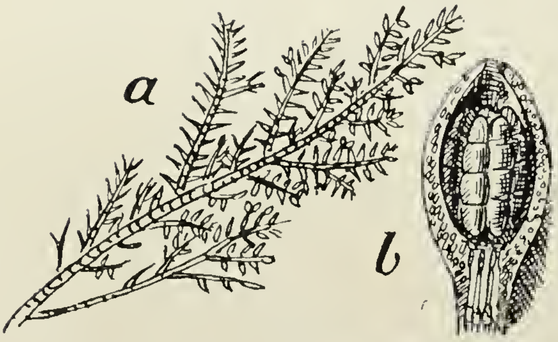


Fig. 680.—Common Coralline (*Corallina officinalis*) (*a*) Portion of the plant. (*b*) Tetraspores.

We now reach the huge assemblage of forms that were until recently grouped together under the general name of Algæ, but are now separated into a number of distinct classes. Many of the species are familiar, as common Seaweeds and plants of fresh-water ponds and streams. As in the case of the Fungi, we can here only give a very brief indication of the characters of each class.

The Rhodophyceæ, or Red Seaweeds, sometimes termed Florideæ, get their name from the fact that in most of the species the chlorophyll in the cells is masked by a red pigment known as phycoerythrin. They are attached by suckers to rocks, shells, or other weeds, but have no true roots, absorption being performed by the surface-cells of the entire thallus. This assumes a great variety of forms, from the mere threads of *Batrachospermum* and *Callithamnium*, consisting of a single row of cells, to the broad leaf-like ribbons of *Delesseria* with mid-rib and nervures mimicking the leaves of Phanerogams. In *Corallina* (fig. 680) the thallus is so completely invested with a layer of calcium carbonate that its vegetable nature is disguised, and the plants were long regarded as true corals. There is no alternation of generations, but there are two modes of reproduction—sexual and asexual. The asexual mode is by the division of a mother-cell or sporange, usually into four (hence distinguishable by the name of tetraspores), which are set free by the rupture of the sporange walls. These tetraspores are not ciliated, and have no power of motion, but float with the sea currents until they come to rest and vegetate on some suitable surface. The sexual organs are antherids and carpogones. The contents of the antherid, instead of

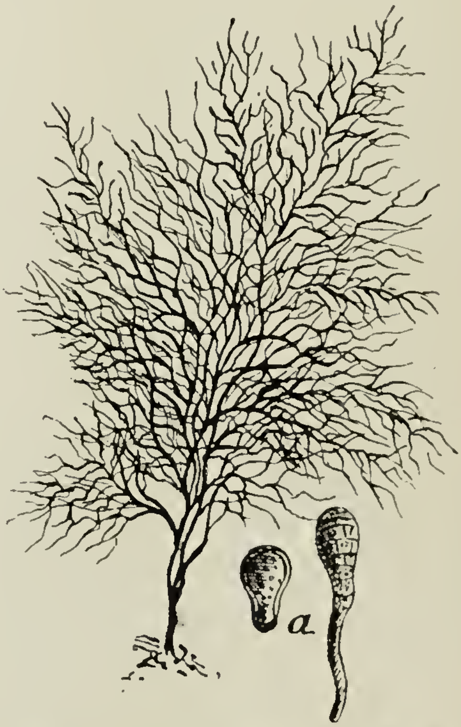


Fig. 681.—Red Seaweed (*Polysiphonia subulata*). (*a*) Tetragonidium of same in two stages of growth.

being broken up into antherozoids, go to form a more or less spherical spermatium. The carpogone has a basal flask-shaped portion surmounted by a filamentous extension, the trichogyne. The basal portion contains the oosperm and the trichogyne serves as a receptive organ for the spermatium. As the spermatia drift helplessly through the water, one or more become attached to the trichogyne, their contents pass through the walls of both organs and reach the oosperm. By a complicated process, varying in different species, there arise a number of carpospores, which are enclosed in a general envelope, the whole body being known as a cystocarp. Ultimately the walls of this are ruptured, and the carpospores thus set free give rise each to a protoneme, from which a thallus is developed. The well-known Carrageen (*Chondrus crispus*) is a member of this class. Speaking of the fertilisation of *Polysiphonia subulata*, which belongs to this class, Professor McAlpine says: "It is evident that the element of chance enters largely into the meeting of the passive male and female elements, and it is not to be wondered at that in many cases fertilisation never takes place at all. Professor Dodel-Port has, however, recently observed that Infusoria create currents in the water and thus set the passive sperm-cells [spermatia] in motion. Numerous Vorticellæ, or Bell-animalcules, attach themselves to this seaweed, and create currents which send the sperm-cells spinning about, while the forked hairs beside the trichogyne help to break the force of the current and cause the sperm-cells to settle there. Just as insects obtain pollen or honey from a flower while unconscious agents in its fertilisation, so do these water animals swallow some of the sperm-cells for their pains. Contrivances in Flowerless Plants for ensuring fertilisation may not be less wonderful, when better known, then those brought to light in Flowering Plants" (figs. 681, 682).

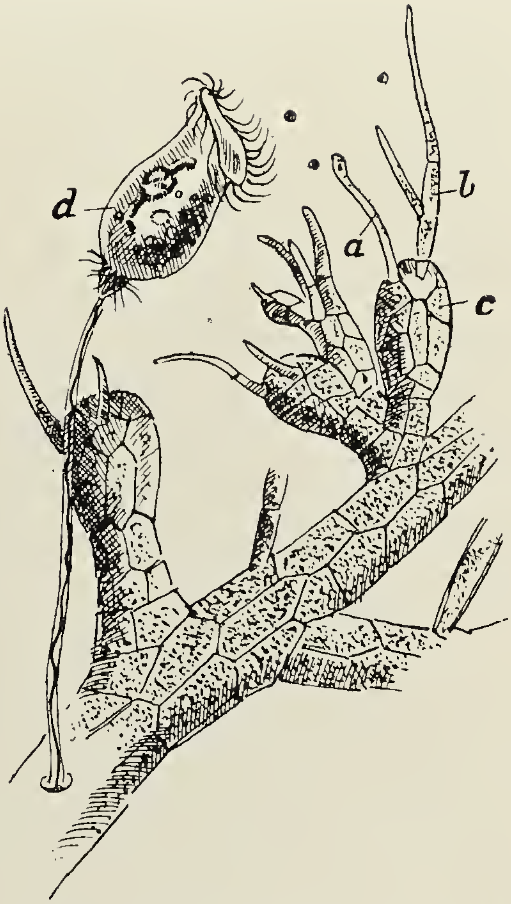
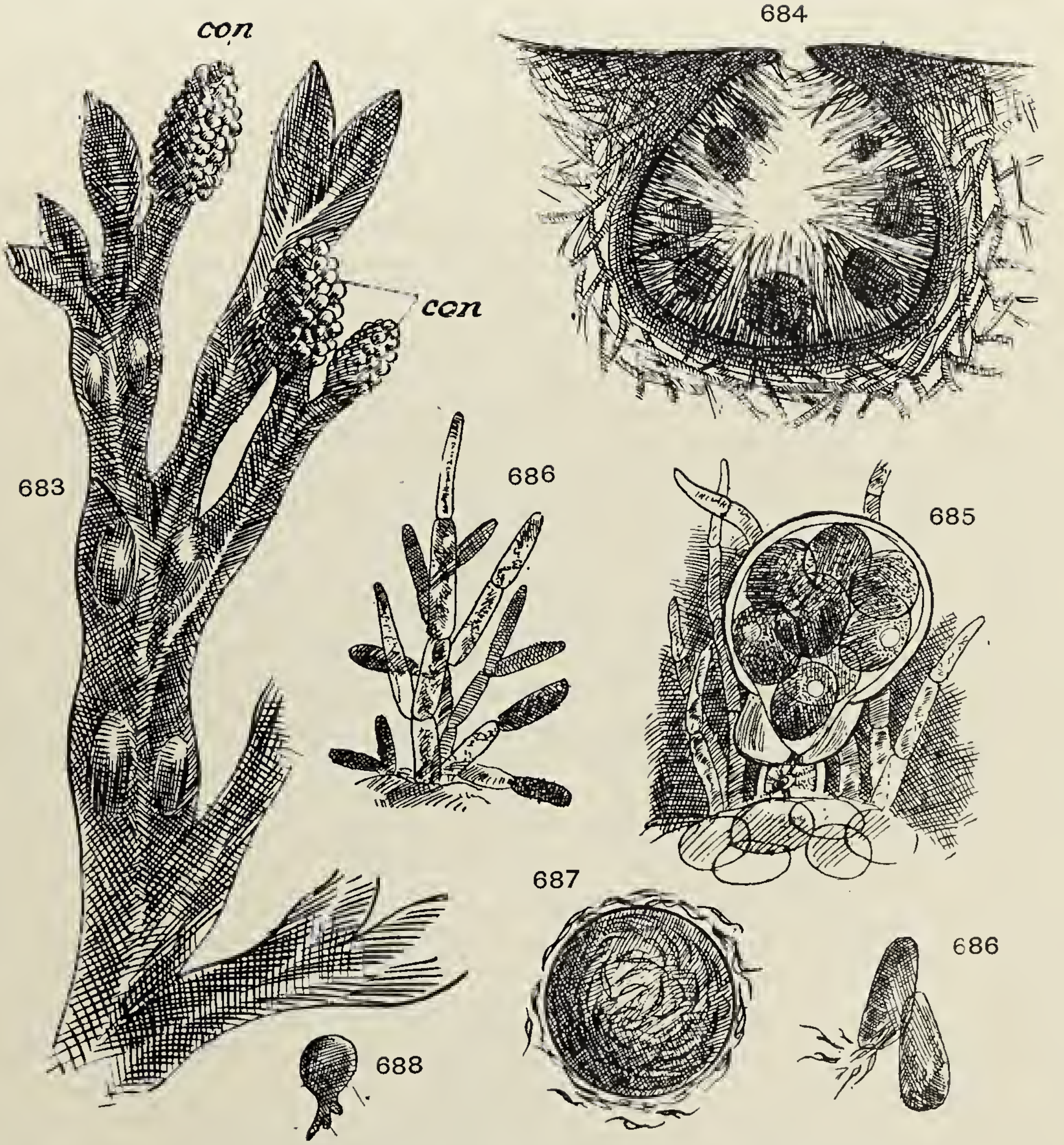


Fig. 682.—Portion of female plant of *Polysiphonia subulata* with Vorticella (*d*). (*a*) Trichogyne. (*b*) Forked hair. (*c*) Sporogone.

The Phæophyceæ, or Brown and Olive Seaweeds, include the Wracks and Tangs, which are abundant and conspicuous on the rocky coasts of the colder seas (figs. 683-689). Here, again, there is great diversity of form, size, and structure, which may be well exemplified by a comparison of the thread-like rows of simple cells in *Ectocarpus* with the broad leathery fronds of *Laminaria* and *Alaria* on our own coasts, the Antarctic *Macrocystis*, with floating ribbons two or three hundred yards long, and the tree-like *Lessonia* of the same regions. Reproduction of the Brown Algæ varies in the several orders. There are asexual swarm-spores produced in large numbers and discharged from lateral sporangia. There are bodies known as gametes formed in gametangia, which resemble the asexual swarm-spores, but which join in pairs, and, as a result of their fusion, give rise to zygotes, from which new plants develop. There are flask-shaped depressions (conceptacles) in the surface of the thallus, within which are produced antherids and oogones, the former discharging motile spermatozoids, and the latter oospheres. In most species the conceptacle is male *or* female; in *Fucus platycarpus* both antherids and oogones are produced in the same conceptacle.

The CHLOROPHYCEÆ, or Green Algæ, are of much simpler structure than the foregoing; many of them consist of a single cell, and some of these, owing to their active motile powers, were formerly considered as low forms of animal life. The methods of reproduction are varied, and sexual union is not general. In the Order Protococcoideæ all the species are unicellular, though in some there is a loose union of a few or many individuals into a colony that may give them the appearance of being multicellular. Some of these are found in all stagnant water and on wet walls and tree-trunks, multiplying by simple division of the cell, or by the breaking up of the protoplasm into a number of swarm-spores, each provided with a couple of cilia. These are set free by the rupture of the cell-wall. The Algæ already referred to as forming one of the elements in the composition of Lichens belong to this order. More strangely still, some of them (*Chlorella*) are found living in the cells of low forms of animal life, such as the Hydra, the Fresh-water Sponge and *Infusoria*, for whom they manufacture starch, which animals are incapable of doing. Another method of reproduction found in this order is by the union of two naked motile masses of protoplasm, known as planogametes, which become fused together and form a zygote, which develops into a cell-family enclosed in a common envelope. The well-known *Volvox*, so long bandied about from zoologist to botanist and *vice versa*, is a hollow colony of single-celled Protococcids, each with its pair of cilia projecting through the common envelope, whose movements give that revolving motion to the colony that has delighted all who have viewed it through the microscope. Within the colony smaller daughter-colonies may be seen revolving; also aggregations of ciliated spermatozoids. Large colonies may contain as many as twenty-two



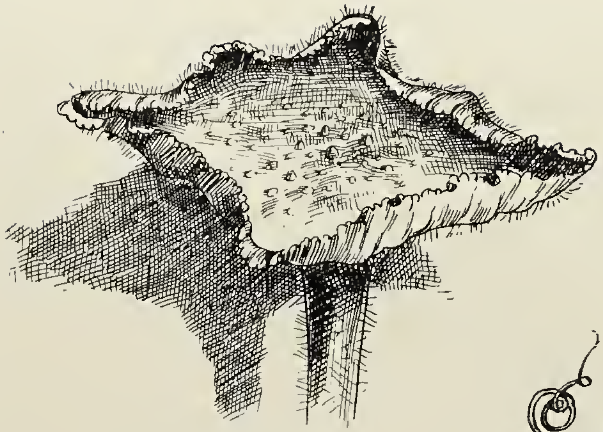
Figs. 683-688.—Life History of Bladder-Wrack (*Fucus vesiculosus*).

Fig. 683.—Fertile branches of the plant; (*con*) conceptacles. Fig. 684.—Section of a conceptacle, showing several oogonia seated in a confused mass of antheridial hairs. Fig. 685.—A single oogonium, distended by its eight oospheres and just ready to split. Fig. 686.—Antheridia; the antherozoids are shown escaping from an antheridium. Fig. 687.—Oosphere swarming with antherozoids, which are fertilising it. Fig. 688.—An oospore in early stage of germination.

thousand individuals, each connected to five or six neighbouring cells by delicate threads of protoplasm. Certain of these cells develop into large egg-cells, which are fertilised by the spermatozoids. These egg-cells may be distinguished from the daughter-colonies by the lack of motion. When the egg-cells are mature, the old colony breaks up into its constituent cells, and the egg-cell (now an oospore) sinks to the bottom, and in a resting condition develops into a new colony. In the Order Confervoideæ the individuals are multicellular, but in most cases the cells are in a single row, placed end to end, and form long fine threads. Some are fresh-water species, some marine, whilst one—*Trentepohlia*—is aerial. They are reproduced asexually by the protoplasm of certain cells breaking up into swarm-spores. There are two forms of sexual reproduction. One is by the fusion of two planogametes, as in Protococcoideæ; the other is by the enlargement of one cell into an oogonium containing a single cell, which is fertilised by a spermatozoid formed in another cell of the same or another filament.

The Class CONJUGATÆ consists of fresh-water Algæ very similar in appearance to the single-celled and filamentous forms of CHLOROPHYCEÆ, but reproduction is effected asexually by simple cell-division, and sexually by the conjugation of two apparently similar cells resulting in the formation of a zygospore.

In certain species of DIATOMEÆ conjugation is effected by two individuals coming together, and after throwing off their siliceous valves the protoplasts become fused to form a new individual, which afterwards multiplies by division. But in the majority of Diatoms there is nothing approaching a sexual union, and the purely vegetative multiplication by division is the rule in the remaining Classes, PERIDINEÆ, SCHIZOPHYTA, and MYXOMYCETES.



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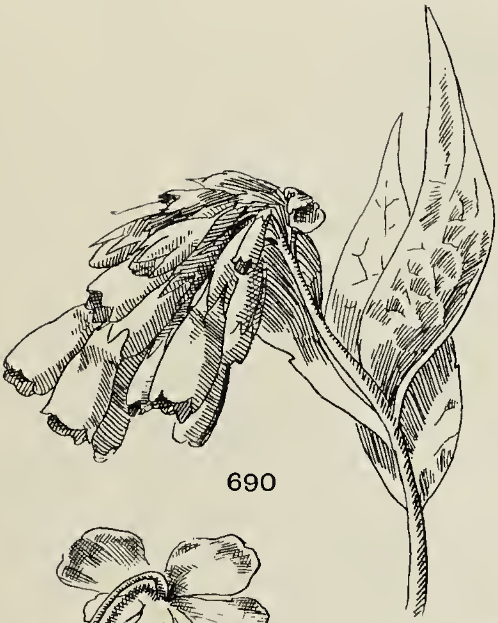

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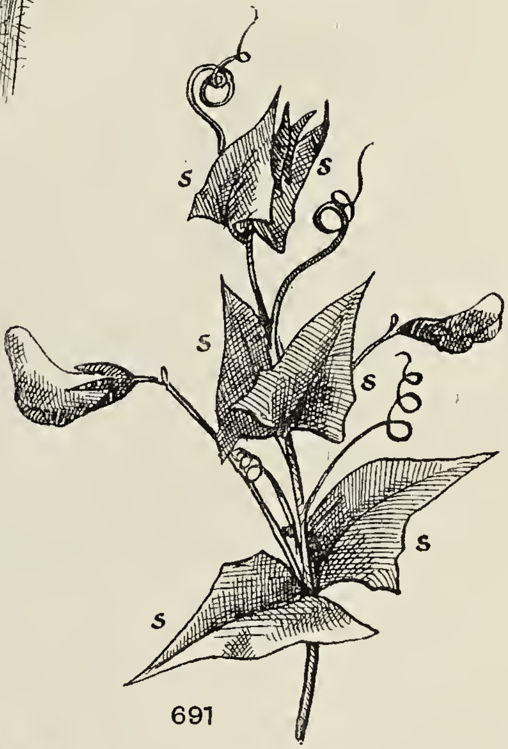

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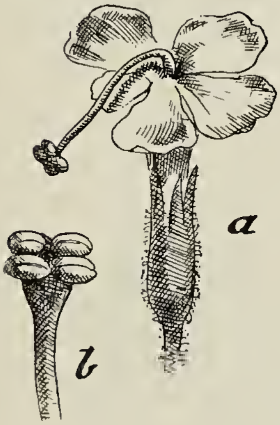

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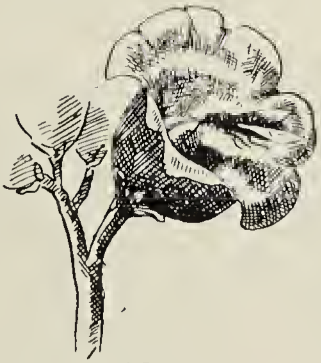

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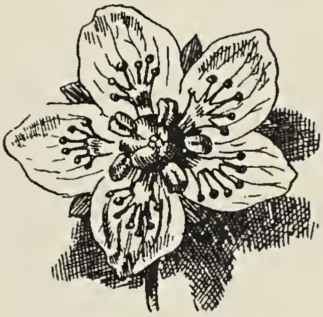

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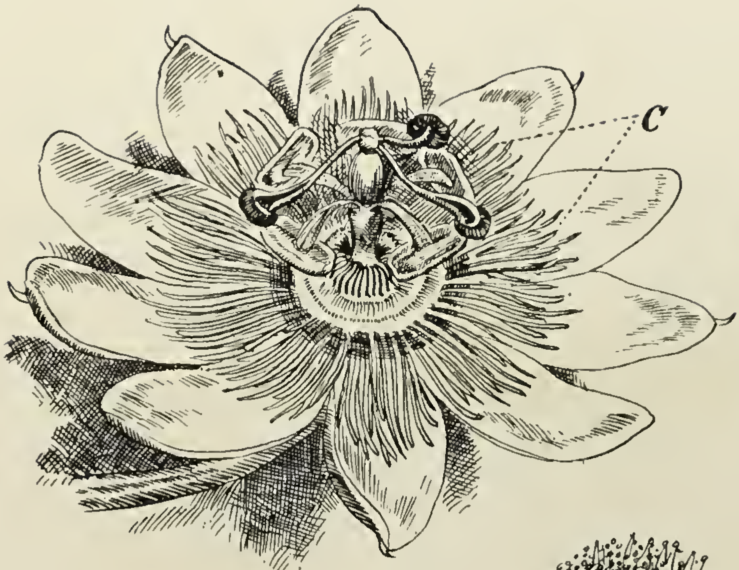
Fig. 689.—Inflorescence of *Dorstenia Contrayerva.* The inconspicuous green flowers are seated on the flattened leaf-like receptacle (*see* pp. 229-35). Fig. 690.—Scorpioid cyme of Comfrey (*Symphytum officinale—see* p. 316). Fig. 691.—Leaf-like stipules of *Lathyrus Aphaea*, the Yellow Vetch (*see* pp. 169-72). Fig. 692.—(*a*) Flower of *Stylidium.* (*b*) Filament of style, forming a single column, with anthers covering stigma (*see* pp. 268-74). Fig. 693.—A fly held fast by stamens of Tutsan-leaved Dogsbane (*see* p. 281). Fig. 694.—Flower of Grass of Parnassus (*Parnassia palustris—see* p. 267).



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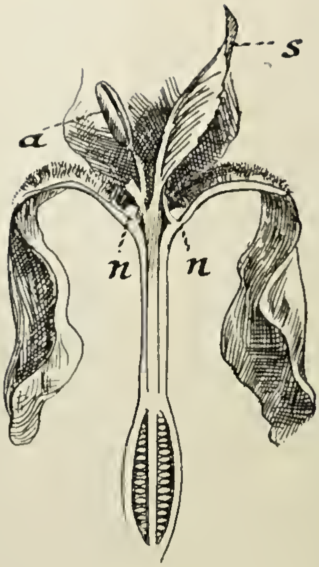

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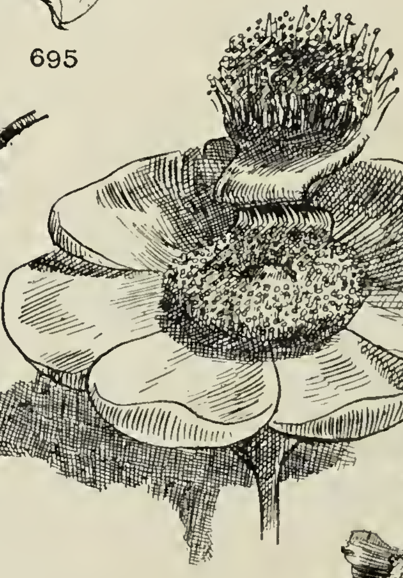

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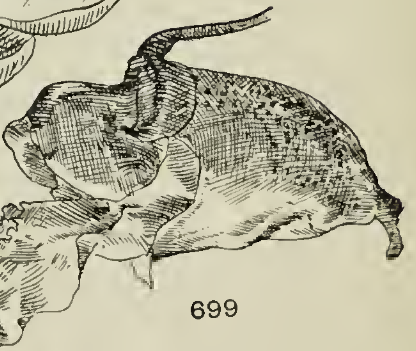

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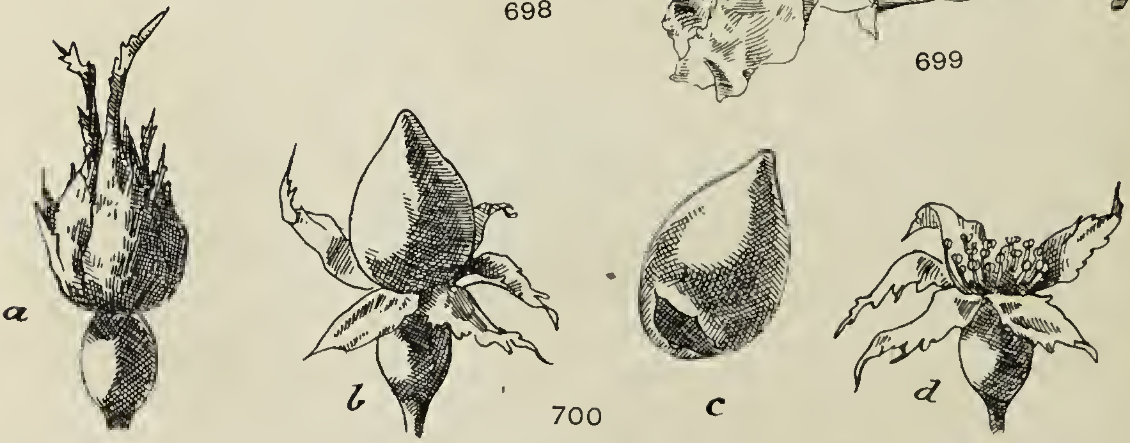

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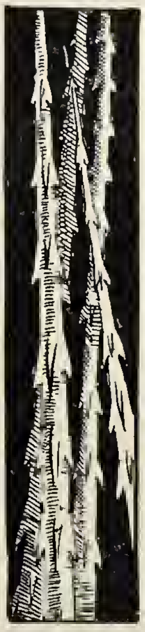
Fig. 695.—Blue Passion-flower (*Passiflora cœrulea*). (*c*) Corona (*see* p. 267). Fig. 696.—Section of flower of Iris. (*a*) Stamen. (*n n*) Nectaries. (*s*) Foliaceous stigma (*see* pp. 271-6). Fig. 697.—Flower-bud of creeping Buttercup (*Ranunculus repens*), showing furrowed stem and bracts (*see* p. 231). Fig. 698.—Flower of the Cannon-ball Tree (*Couroupita guianensis—see* pp. 268-74). Fig. 699.—Flower of Garden Balsam (*Impatiens Balsamina—see* pp. 261, 262). Fig. 700.—Cleistogamic bud of Dog-rose (*Rosa canina*). (*a*) The unopened bud. (*b*) The same, with calyx expanded. The cohering petals form a cap which covers the stamens. (*c*) The cap removed. (*d*) The bud after removal of the cap (*see* p. 288).



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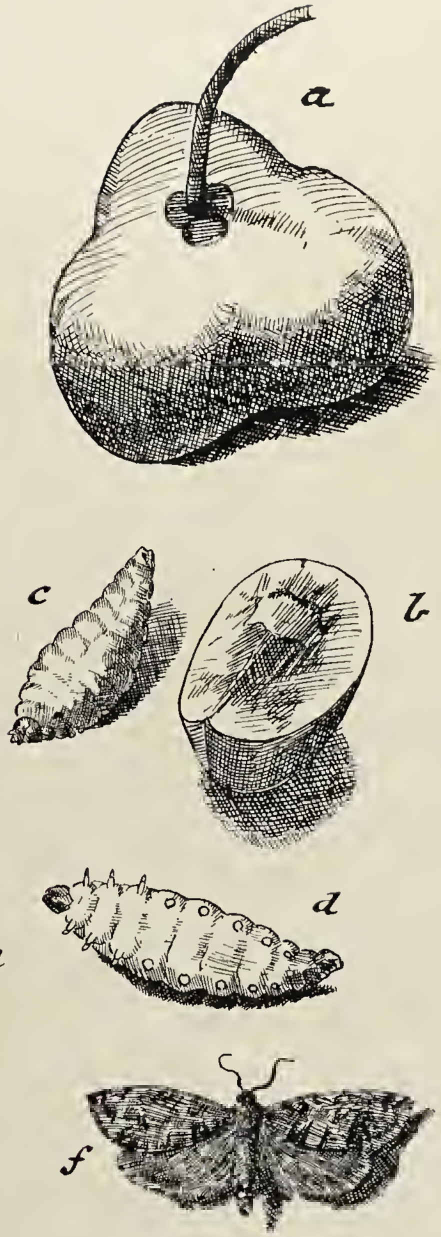

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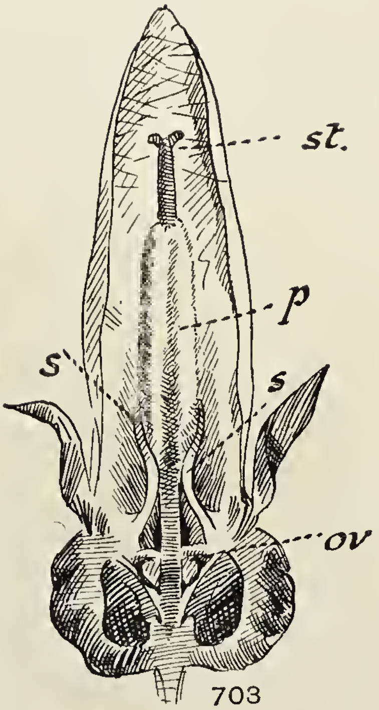

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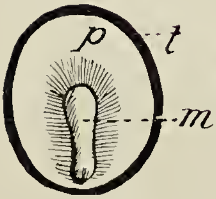

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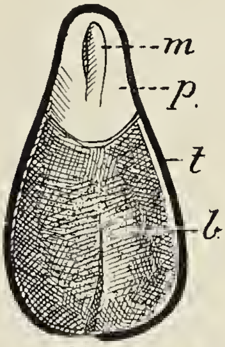

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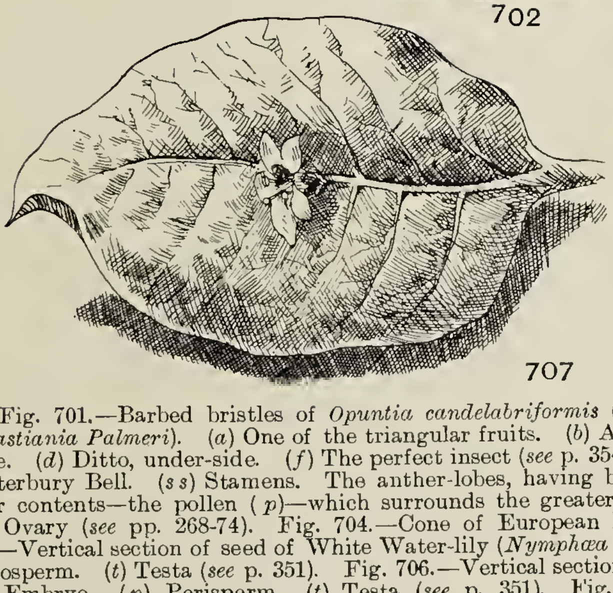

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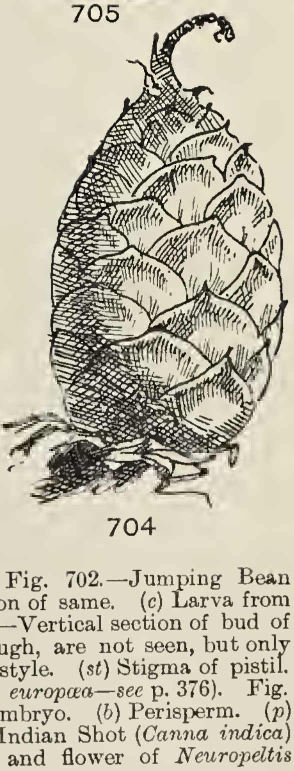

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Fig. 701.—Barbed bristles of *Opuntia candelabriformis* (*see* p. 219). Fig. 702.—Jumping Bean (*Sebastiania Palmeri*). (*a*) One of the triangular fruits. (*b*) A single division of same. (*c*) Larva from same. (*d*) Ditto, under-side. (*f*) The perfect insect (*see* p. 354). Fig. 703.—Vertical section of bud of Canterbury Bell. (*s s*) Stamens. The anther-lobes, having been cut through, are not seen, but only their contents—the pollen (*p*)—which surrounds the greater part of the style. (*st*) Stigma of pistil. (*ov*) Ovary (*see* pp. 268-74). Fig. 704.—Cone of European Larch (*Larix europæa*—*see* p. 376). Fig. 705.—Vertical section of seed of White Water-lily (*Nymphæa alba*). (*m*) Embryo. (*b*) Perisperm. (*p*) Endosperm. (*t*) Testa (*see* p. 351). Fig. 706.—Vertical section of seed of Indian Shot (*Canna indica*) (*m*) Embryo. (*p*) Perisperm. (*t*) Testa (*see* p. 351). Fig. 707.—Bract and flower of *Neuropeltis racemosa* (*see* p. 232).

GLOSSARY OF TERMS

[*Note*—As the application of these terms has been fully explained in the text, the repetition of the same here has been considered unnecessary.]

Achene; Gr. *a*, not, and *chaino*, I open
Acicular; Lat. *acicula*, a small needle
Actinomorphic; Gr. *aktis*, a ray, and *morphe*, a shape
Æstivation; Lat. *æstas*, summer
Aleurone; Gr. *aleuron*, ground wheat
Allogamy; Gr. *allos*, other, and *gamos*, marriage
Amentum; Lat. a thong
Amplexicaul; Lat. *amplexus*, embracing, and *caulis*, stem
Anatropous; Gr. *anatrepō*, to turn in or over
Anemophilæ; Gr. *anemos*, the wind, and *phileo*, to love
Annular; Lat. *annulus*, a ring
Annulated; Lat. *annulatus*, ringed
Annulus; Lat. a ring
Andrœcium; Gr. *andros*, a male, and *oikos*, a house
Angiosperm; Gr. *aggeion*, a vessel, and *sperma*, seed
Anthers; Gr. *antheros*, flowery
Antherid; Gr. *antheros*, and *idion*, a diminutive suffix
Antherozoid; Gr. *antheros*, and *zoon*, an animal
Anthocyanin; Gr. *anthos*, flower, and *kuaneos*, dark blue
Antipodal; Gr. *anti*, opposite, and *pous*, foot
Apocarpous; Gr. *apo*, separate, and *karpos*, fruit
Apogamy; Gr. *apo*, and *gamos*, marriage
Archegone; Gr. *archē*, a beginning, and *gonē*, birth, production
Archespore; Gr. *archē*, and *sporos*, seed
Ascidiform; Gr. *askidion*, a little bottle
Auriculate; Lat. *auricula*, an ear
Autogamy; Gr. *autos*, self, and *gamos*, marriage

Bract, Bracteate; Lat. *bractea*, a thin plate of metal

Caducous; Lat. *cado*, I fall
Calceolate; Lat. *calceolus*, a slipper
Calypter; Gr. *calyptra*, a covering or veil
Calyx; Lat. *calix*, a cup
Cambium; Lat. *cambio*, I exchange
Campanulate; Ital. *campana*, a bell
Campylotropous; Gr. *campulus*, curved
Capitulum; Lat. a little head
Carpel; Gr. *karpos*, fruit
Carposperm; Gr. *karpos*, and *sperma*, seed
Caryophyllaceous; Gr. *karuophullon*, the clove-tree
Caryopsis; Gr. *karuon*, a nut, and *opsis*, appearance
Cauline; Lat. *caulis*, a stem
Chlorophyll; Gr. *chloros*, green, and *phullon*, a leaf
Circinate; Lat. *circinatus*, rounded
Cladode; Gr. *klados*, a branch
Cleistogamic; Gr. *kleistos*, closed, and *gamos*, marriage
Coleorhiza; Gr. *koleos*, a sheath, and *rhiza*, root
Collenchyma; Gr. *kolla*, glue, and *enchuma*, something poured in
Columel; Lat. *columella*, a little column
Conduplicate; Lat. *conduplicatus*, doubled
Connate; Lat. *con*, together, and *natus*, born
Convolute; Lat. *convolutus*, rolled up
Cordate; Lat. *cor*, the heart
Corm; Gr. *kormos*, a stem or trunk
Cormophyte; Gr. *kormos*, and *phuton*, a plant
Corolla; Lat. diminutive of *corona*, a crown
Cotyledon; Gr. *kotuledon*, a cup-shaped cavity
Cremocarp; Gr. *kremannumi*, to hang, and *karpos*, fruit
Crenate; Lat. *crena*, a notch
Cruciform; Lat. *crux*, a cross, and *forma*, form
Cryptogam; Gr. *kruptos*, hidden, and *gamos*, marriage
Cucullate; Lat. *cucullus*, a hood or cowl
Cuneate; Lat. *cuneus*, a wedge
Cyanic; Gr. *kuaneos*, dark blue
Cyanophyll; Gr. *kuaneos*, and *phullon*, leaf
Cystoliths; Gr. *kustis*, a bag or bladder, and *lithos*, a stone

Deciduous; Lat. *decidere*, to fall

Decurrent; Lat. *de*, down, and *curro*, to run
Decussate; Lat. *decusso*, to divide crosswise
Dehisce; Lat. *dehiscere*, to gape
Dentate; Lat. *dens*, a tooth
Dichogamy; Gr. *dicha*, in two parts, and *gamos*, marriage
Dichotomous; Gr. *dicha*, and *tome*, to cut
Digitate; Lat. *digitus*, a finger
Diœcious; Gr. *di*, two, and *oikos*, a house
Distichous; Gr. *di*, and *stichos*, a row

Elater; Gr. an impeller
Emarginate; Lat. *e*, privative, and *margo*, a margin
Endocarp; Gr. *endon*, within, and *karpos*, fruit
Endosmose; Gr. *endon*, within, and *ōsmos*, impulsion
Endosperm; Gr. *endon*, and *sperma*, seed
Endospore; Gr. *endon*, and *sporos*, seed
Entomophilæ; Gr. *entoma*, insects, and *phileo*, to love
Epicarp; Gr. *epi*, upon, and *karpos*, fruit
Epidermis; Gr. *epi*, and *derma*, skin
Epiphyllous; Gr. *epi*, and *phullon*, a leaf
Epispore; Gr. *epi*, and *sporos*, seed
Exosmose; Gr. *exo*, outside, and *ōsmos*, impulsion
Exospore; Gr. *exo*, and *sporos*, seed
Extrorse; Lat. *extrorsum*, outwards

Fascicular; Lat. *fasciculus*, a small bundle
Filament; Lat. *filum*, a thread
Filiform; Lat. *filum*, and *forma*, form
Fistular; Lat. *fistula*, a pipe
Fusiform; Lat. *fusus*, a spindle, and *forma*, form

Galeate; Lat. *galea*, a helmet
Gamete; Gr. wife or husband
Gamopetalous; Gr. *gamos*, marriage, and petal. Applied to corolla
Gamosepalous; Gr. *gamos*, and sepal. Applied to calyx
Gibbous; Lat. *gibbosus*, humped
Glume; Lat. *gluma*, a husk
Gluten; Lat. paste
Gymnosperm; Gr. *gumnos*, naked, and *sperma*, seed
Gymnostomous; Gr. *gumnos*, and *stoma*, a mouth
Gynœcium; Gr. *gunē*, a female, and *oikos*, a house
Gynandrous; Gr. *gunē*, and *andros*, a male

Hastate; Lat. *hasta*, a spear
Heterophyllous; Gr. *heteros*, different, and *phullon*, a leaf
Heterostylism; Gr. *heteros*, and style
Hilum; Lat. a very small thing
Hydrophilæ; Gr. *udor*, water, and *phileo*, to love
Hypocrateriform; Gr. *hypo*, under, and *krater*, a goblet

Indusium; Lat. an under-garment
Inflorescence; collective name for all the flowers produced on one floral shoot
Infundibuliform; Lat. *infundibulum*, a funnel
Introrse; Lat. *introrsum*, inwards
Involucre; Lat. *involucrum*, a wrapper
Involute; Lat. *involutus*, wrapped up

Labiate; Lat. *labium*, a lip
Laciniated; Lat. *lacinia*, a fringe or border
Latex; Lat. juice
Legumin; Lat. pulse
Leukoplasts; Gr. *leukos*, white, and *plasma*, that which has been formed
Loculicidal; Lat. *loculus*, a little place, and *cædo*, to cut

Malacophilæ; Gr. *malakos*, soft [mollusc], and *phileo*, to love
Manubrium; Lat. a handle
Medullary; Lat. *medulla*, the marrow
Megaspore; Gr. *mega*, great, and *sporos*, seed
Meristem; Gr. *meristos*, divided
Mesocarp; Gr. *mesos*, middle, and *karpos*, fruit
Metabolism; Gr. *metabolē*, a changing
Micropyle; Gr. *mikros*, little, and *pulē*, a gate
Microspore; Gr. *mikros*, and *sporos*, seed
Monadelphous; Gr. *monos*, sole, and *adelphos* brother
Moniliform; Lat. *monila*, a necklace
Monœcious; Gr. *monos*, one, and *oikos*, a house
Mucronate; Lat. *mucro*, a sharp point
Multicellular; made up of many cells
Mycele; Gr. *mukos*, mushroom, and *kele*, a tumour

Napiform; Lat. *napus*, a turnip, and *forma*, form
Nodulose; Lat. *nodus*, a knot
Nucellus; Lat. *nucula*, a small nut
Nucleus; Lat. *nux*, a nut or kernel

Obcordate; Lat. *ob*, inversely, and *cor*, the heart

Obovate; Lat. *ob*, and *ovatus*, egg-shaped
Oophyte; Gr. *oon*, an egg, and *phuton*, a plant
Oosperm; Gr. *oon*, and *sperma*, seed
Oosphere; Gr. *oon*, and *sphaira*, a sphere
Orbicular; Lat. *orbiculus*, a small disc
Ornithophilæ; Gr. *ornithos*, a bird, and *phileo*, to love
Orthotropous; Gr. *orthos*, straight
Ostiolum; Lat. diminutive of *ostium*, a door
Ovary, Ovule; Lat. *ovum*, an egg

Pales; Lat. *palea*, chaff
Palmate; Lat. *palma*, the palm of the hand
Panicle; Lat. *panicula*, cat's-tail
Papilionaceous; Lat. *papilio*, a butterfly
Pappus; Gr. *pappos*, the down of plants
Paraphyse; Gr. *paraphus*, growing beside
Parenchyma; Gr. *parenchuma*, the spongy substance of the lungs
Paripinnate; Lat. *par*, equal, and *pinnatus*, feathered
Pedate; Lat. *pedatus*, from *pes*, foot
Pedicel, pedicillate, peduncle; Lat. diminutives of *pes*, *pedis*, the foot
Peloria; Gr. *pelōron*, a monster
Peltate; Lat. *pelta*, a shield
Perfoliate; Lat. *per*, through, and *folium*, a leaf
Perianth; Gr. *peri*, about, and *anthos*, a flower
Pericarp; Gr. *peri*, and *karpos*, fruit
Perichæte; Gr. *peri*, and *chaite*, flowing hair
Perigone; Gr. *peri*, and *gone*, womb
Perisperm; Gr. *peri*, and *sperma*, seed
Peristome; Gr. *peri*, and *stoma*, a mouth
Personate; Lat. *personatus*, masked
Petal; Fr. *pétale*, a leaf, used in reference to floral leaves only
Phanerogam; Gr. *phaneros*, evident, and *gamos*, marriage
Phloëm; Gr. *phloios*, inner bark
Phyco-erythin; Gr. *phukos*, sea-weed, and *erythros*, red
Phylloclades; Gr. *phullon*, a leaf, and *klados*, a branch
Phyllode; Gr. *phullon*, and *eidos*, likeness
Phyllotaxy; Gr. *phullon*, and *taxis*, order
Phylloxanthin; Gr. *phullon*, and *xanthos*, yellow
Pileorhiza; Gr. *pileus*, a cap, and *rhiza*, root
Pileus; Gr. a cap or helmet
Pinnatifid; Lat. *pinnatus*, feathered, and *findo*, I split
Pinnatisect; Lat. *pinnatus*, and *seco*, I cut
Pistil; Lat. *pistillum*, a pestle
Plicate; Lat. *plica*, a fold
Plumule; Lat. *pluma*, a feather
Pollen; Lat. fine flour or dust
Polyadelphous; Gr. *polus*, many, and *adelphos*, brothers
Primine; Lat. *primus*, first
Procarp; Gr. *protos*, first, and *karpos*, fruit
Prosenchyma; Gr. *pros*, beside, and *enchuma*, something poured in
Proteus; a fabulous person who could change his form at will
Proterandrous; Gr. *proteros*, before, and *andros*, male
Proterogynous; Gr. *proteros*, and *gunē*, female
Prothallium; Gr. *proteros*, and *thallos*, a shoot
Protoneme; Gr. *prōtos*, first, and *nema*, a thing spun, a thread
Protophyte; Gr. *protōs*, and *phuton*, a plant
Protoplasm; Gr. *prōtos*, and *plasma*, that which has been formed
Pseudocarp; Gr. *pseudōs*, false, and *karpos*, fruit
Pulvinus; Lat. a cushion
Pyxis; Gr. *puxidion*, a little box

Rachis; Gr. the spine
Radicle; Lat. *radix*, a root
Raphides; Gr. *raphis*, a needle
Reniform; Lat. *ren*, a kidney, and *forma*, form
Replum; Lat. *replum*, the leaf of a door
Reticulated; Lat. *reticulum*, a small net
Retuse; Lat. *re*, back, and *tundo*, I hammer
Revolute; Lat. *revolutus*, rolled back
Rostellum; Lat. diminutive of *rostrum*, a beak
Runcinate; Lat. *runcina*, a saw

Saccate; Lat. *saccus*, a bag
Sagittate; Lat. *saggita*, an arrow
Saprophyte; Gr. *sapros*, rotten, and *phuton*, a plant
Sarcocarp; Gr. *sarkos*, flesh, and *karpos*, fruit
Scalariform; Lat. *scala*, a ladder
Scape; Lat. *scapus*, a stalk
Schizocarp; Gr. *schizo*, to split, and *karpos*, fruit
Sclerenchyma; Gr. *skleros*, hard, and *enchuma*, anything poured or put in
Secundine; Lat. *secundæ*, second
Sepal; Fr. *sépale*, invented term to correspond with *pétale*
Septicidal; Lat. *septum*, an enclosure, and *cædo*, to cut
Septifragal; Lat. *septum*, and *frango*, to break
Sessile; Lat. *sessilis*, sitting
Sorus; Gr. *soros*, a heap
Spadix; Lat. a palm-branch
Spathe; Gr. *spathē*, a broad blade
Spathulate; Lat. *spathula*, a broad slice
Spermocarp; Gr. *sperma*, seed, and *karpos*, fruit

Sporange; Gr. *sporos*, seed, and *aggeion*, a vessel
Spore; Gr. *spora*, seed
Sporocarp; Gr. *sporos*, and *karpos*, fruit
Sporogenous; Gr. *sporos*, and *genao*, to produce
Sporophyll; Gr. *sporos*, and *phullon*, a leaf
Sporophyte; Gr. *sporos*, and *phuton*, a plant
Stamen; Lat. a fibre
Stigma; Gr. *stigmē* a point
Stomate; Gr. *stoma*, a mouth
Style; Lat. *stylus*, a stake
Subulate; Lat. *subula*, an awl
Synantherous; Gr. *sun*, together, and anther
Syncarpous; Gr. *sun*, and *karpos*, fruit
Synergidæ; Gr. *sun*, and *ergon*, work

Testicular; Lat. *testis*, a testicle
Tetraspore; Gr. *tetra*, four, and *sporos*, seed
Thallophyte; Gr. *thallos*, a shoot, and *phuton*, a plant
Tomentose; Lat. *tomentum*, down
Trichogyne; Gr. *trichos*, hair, and *gunē*, female
Truncate; Lat. *trunco*, to maim or cut off

Urceolate; Lat. *urceus*, a pitcher
Utricular; Lat. *utriculus*, a little bottle

Vernation; Lat. *ver*, the spring
Versatile; Lat. *versatilis*, revolving
Verticillate; Lat. *verticillis*, a little whorl

Xanthic; Gr. *xanthos*, yellow
Xylem; Gr. *xulon*, wood or timber

Zoophilæ; Gr. *zoon*, animal, and *phileo*, to love
Zoospore; Gr. *zoon*, an animal, and *sporos*, seed
Zygote, Zygomorphic; Gr. *zeugnumi*, I join, and *morphe*, a shape

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INDEX

(Scientific names of plants, organs, etc., printed in *italics.*)

Abies canadensis, 44
Abnormal flowers, 241
Absorption, 58
Abutilon, 337
Acacia, 160, 201, 211, 361
Acanthus, 219, 359
Accrescent calyx, 251
Acer, 36, 138, 192, 372
Achene, 369
Achlya, 395
Acicular leaf, 195, 219
Acid sap, 59
Aconitum, 125, 177, 181, 250
Acotyledons, 118
Actæa, 184
Actinomorphic flowers, 253
Acuminate apex, 198
Acute apex, 198
Adansonia digitata, 126
Adhesion, 248
Adnate anther, 269
Adonis, 302
Adventitious buds, 172
Adventitious roots, 114
Æsculus, 45, 169, 181, 363
Æstivation, 244
African Marigold, 88
Agaricus, 95, 96, 98, 108
Agarum, 208
Agassiz and botany, 2
Agave, 219
Aggregate fruits, 356
Agrostemma, 34, 191
Alæ, 263
Alaria, 400
Albuminous seed, 351
Albuminous tissue, 116
Algæ, 22, 55, 86, 94; red, 393, 398; brown, 393, 399; green, 393, 400; conjugate, 393
Allen, Grant, on *Primula*, 297
Allium, 42, 209
Allogamy, 249
Almond, 44
Alocasia, 336
Aloe, 45
Alpine Liane, 250, 314
Alpine Madwort, 210
Alternate leaves, 192
Alternation of generations, 390
Althæa, 244
Alyssum, 210
Amentum, 344
American forests, spring coloration of, 31
American Laurel, 325
Amœba, 10
Amorphophallus, 301
Ampelopsis, 301
Amplexicaul leaf, 186
Anacardiaceæ, 45
Anagallis, 192, 359
Ananassa, 356
Anastatica, 362
Anatropous ovule, 349
Andreaceæ, 392
Andrœcium, 267
Andropogon, 44, 92
Androsace, 255
Anemone, 232, 315
Anemophilæ, 338
Angiosperms, 344
Animal and plant mimicry, 9
Animal characteristics, 9
Annual plants, 152
Annual rings, 146
Annulus, 380
Anonaceæ, 270
Antennæ of Orchids, 331
Anther, 238
Antheridium, 110, 113
Antherids, 377, 380, 396
Anthers : versatile, 268; sessile, 269; basifixed, 269; dorsifixed, 269; innate, 269; adnate, 269; introrse, 269; extrorse, 269; forms of, 271
Antherozoid, 380, 385, 391, 396
Anthocyanin 204, 302,
Anthodium, 234
Anthornis, 337
Anthoxanthum, 185
Antiaris toxicaria, 38
Antipodal cells, 350
Antirrhinum, 233, 239, 244, 259, 279, 316
Ants and Milk-sap of Lettuce, 37
Apocarpous pistils, 248
Apocynum, 281
Apogamy, 382
Apospory, 380
Apple, 276
Aquilegia, 259, 360
Arachis, 41, 361
Aralia, 301
Araujia, 327
Archegones, 110, 113, 377, 380, 385
Archegonium, 110, 113
Archespore, 379
Aretia, 255
Argemone, 291
Arillus, 374
Aristolochia, 269, 295, 308, 322
Aroids, 208
Aromatic oils, 43
Arrow-grass, 347
Arrow-head, 190, 285
Artillery-plant, 346
Artocarpus, 33, 356
Arum, 31, 180, 231, 302, 306
Ascidiform leaf, 201
Asclepias, 161, 326
Ash, 284
Aspen, 216
Asperula, 153
Aspidistra, 297
Aspidium, 380
Asplenium, 173, 380
Assimilation, 83
Astragalus, 39
Atragene, 250, 314
Attar of Roses, 43
Auriculate leaf, 195
Autogamy, 249, 285
Avena, 34, 233
Avebury, Lord, on flower defences, 280
Awl-shaped leaf, 193
Awn, 233
Axillary buds, 172
Axillary flowers, 229
Azolla, 378

Bacilli, 15, *and note*
Bacteria, 15, 22
Balanophora, 101
Ballota, 373
Balsams, 44, 288, 316, 373
Bamboo, 43, 154
Bambusa, 154
Banana, 146
Baneberry, 184
Banyan, 133, 162
Baobab, 126
Barbed bristles, 219
Barberry, 116, 311, 325
Barley, 115, 191

Basal style, 272
Basidiomycetes, 395
Basifixed anther, 269
Bast-fibres, 51
Bast-tissues, 144
Batrachospermum, 398
Bauhinia, 150
Bay-tree, 172
Beale, Prof., on growth, 42
Bean, 22, 150, 263, 315, 316, 361
Bedeguar, 223
Bedstraws, 153
Beech, 175, 369
Beetroot, 36
Begonia, 172, 194, 242, 276, 336
Bellis, 189, 229, 241, 264
Bell-shaped corolla, 256
Bennett and Murray on vascular cryptogams, 377
Berberis, 116, 311, 325
Bermuda-grass, 130
Berry, 368
Beta vulgaris, 36
Betula, 44, 138
Biennial Plants, 152
Bignoniaceæ, 373
Bindweed, 244
Biogenesis, 5
Bipinnate, 180
Birch, 44, 138
Bird-pollination, 337
Birds and nuts, 369
Bird's-foot Trefoil, 279
Birthwort, 269, 295
Bisexual flowers, 284
Biternate, 184
Bitter Cress, 288
Bitter Cucumber, 374
Bittersweet, 158, 195
Blackberry, 356
Black Horehound, 373
Blackthorn, 155, 218
Blackwood-tree, 160
Bladderwort, 69
Blade of leaf, 179
"Bloom" of leaves and fruit, 46
Blue-bell, 247
Blue-bottle, 372
Boehmeria, 43
Bog-moss, 26
Bomarea, 80
Bombax, 162
Borage, 302
Borago, 302
Botany, meaning of the term, 8
Bo-tree, 166
Botrychium, 383, 384
Bottle-tree, 151
Bracken, 379
Bracteate flowers, 231
Bracts, 231
Bramble, 157
Branched hairs, 210
Brassica, 116, 125, 210
Brazilian Balsam-tree, 133
Bread-fruit, 33, 34, 356
Brooklime, 316
Broom-rape, 101, 178
Brown Algæ, 393, 399
Brownea, 336
Brugmansia, 337
Bryonia dioica, 157
Bryony, White, 157
Bryophyllum, 173
Bryophyta, 390
Buckbean, 30
Buds: adventitious, 172; axillary, 172; epiphyllous, 172; root, 172; terminal, 172
Bud-scales, 169
Bulbils, 172, 382
Bulbs, 147
Bulrush, 342
Bupleurum, 186, 191
Burweed, 364
Bush-rope, 150
Butcher's Broom, 154
Butcher's Broom *Helwingia*, 174
Butomus, 22
Buttercup, 186, 233, 238, 239, 251, 254, 276, 284, 311
Butterworts, 68
Buttress-tree, 151
By-products, 39

Cabomba, 203
Cactaceæ, 41, 45, 80, 156, 162, 178
Cactus, 41, 210; Old Man, 42; Monster, 162
Caducous calyx, 251
Caladium, 240
Calamus, 159
Calceolaria, 261, 271, 301, 308
Calceolate corolla, 261
Calendula vulgaris, 88
Calla, 306, 335
Callithamnium, 398
Calypter, 111, 391
Calyx, 238; galeate, 250; spurred, 250; persistent, 251; deciduous, 251; caducous, 251; accrescent, 251; saccate, 252; globose, 252; tubular, 252; dentate, 254
Cambium, 144
Camellia, 244
Campanula, 256, 279
Campanulaceæ, 295
Campanulate corolla, 256
Camphor, 44
Campion, White, 254
Campylotropous ovule, 349
Candytuft, 363
Cane, 159
Canna, 33, 118
Canose, 36
Canterbury Bell, 256, 279
Caoutchouc, 36
Capitulum, 234, 396
Capsella, 294, 349, 363
Capsule, 356
Carbon dioxide, 58
Carbonic acid, 58
Cardamine, 173, 288, 314, 361
Carduus, 219
Carex arenaria, 127
Carina, 263
Carlina, 371
Carline-thistle, 371
Carludovica, 158
Carnation, 254
Carpels, 238, 247
Carpophore, 372
Carrageen, 399
Carrot, 125, 250, 276, 316
Caryophyllaceous corolla, 254
Caryophyllaceæ, 45
Caryopsis, 370
Cassia, 337
Castanea, 163, 285
Castor-oil Plant, 41
Catasetum, 330
Catchfly, 254, 281
Caterpillar-plant, 361
Catkin, 234
Cat's-foot, 189
Caudex, 150
Caudicles, 328
Cauline leaf, 194
Caulotretus, 152
Cedar, 166
Cedrus, 55, 166
Celandine, 36, 173
Cell-communities, 47
Cell-divisions, 12, 48
Cell-fusion, 49
Cells, 13, 21
Cells: pitted or dotted, 25; stellate, 21; spindle-shaped, 25; spiral, 26; annular, 27; spiro-annular, 27; reticulated, 27
Cellulose, 17, 23, 32
Centaurea, 185, 241, 281, 290, 372
Cephaëlis, 127
Cephalotus, 72, 201
Cerasus, 175, 316
Ceratopteris, 173
Ceropegia, 161, 322
Ceterach, 171
Chara, 396
Characeæ, 393, 396
Cheiranthus, 233, 362
Chelidonium majus, 36, 173
Cherry, 175, 177, 229, 246, 316
Chestnut, 23, 163, 164
Chicory, 34
Chiococca, 21
Chlora, 186
Chlorella, 400
Chlorophyceæ, 393, 400
Chlorophyll, 19, 28, 378
Chondrus, 399
Chrysanthemum, 264
Cichorium, 34, 191
Cicuta, 46
Cinnamon, 44
Cinquefoil, 187
Circæa, 241
Circinate vernation, 174, 383
Circular æstivation, 244
Circulation, 18
Circumnutation, 150, 161
Cirsium, 353
Citric acid, 35
Citron, 307
Citrullus, 374
Cladodes, 154
Clarkia, 279, 320
Clary, Wild, 26
Clawed petals, 252
Cleavers, 364
Cleistogamic flowers, 286
Clematis, 157, 242
Climbing Cobæa, 291

Climbing Palms, 159
Climbing plants, 157
Clover, 102, 279
Cloves, 45
Club-mosses, 379, 387
Clusia, 133
Cnicus, 186
Cobœa, 291, 318
Coco-nut, 43, 116, 367
Cocos, 116, 367
Cœlogyne, 309
Coffea, 118
Coffee, 118
Cohesion, 246
Coix, 371
Colchicum, 357
Collective fruits, 356
Collenchyma, 53
Colt's-foot, 372
Columbine, 259, 360
Columel, 382, 392
Comfrey, 316
Compass-plant, 211
Complete flowers, 284
Compositæ, 265, 281, 285, 295
Composite flowers, 264
Compound leaf, 180
Compound pistils, 248
Compound umbel, 234
Conceptacles, 400
Conditions of plant life, 200
Conduplicate vernation, 175
Cone, 234
Cone-bearing plants, 27
Confervoideæ, 402
Coniferæ, 27, 45, 55, 119, 342
Conifers, 195
Conjugatæ, 393, 402
Conjugates, 393, 402
Conjugation, 402
Conjugation of cells, 48
Connate leaf, 186
Connective, 238
Conspicuousness of flowers, 300
Convallaria, 147, 230
Convolute vernation, 175
Convolvulus, 157, 244, 256
Convolvulaceæ, 232
Corallina, 398
Cordate leaf, 187
Cordyceps, 104
Cork, 13, 24, 25
Corms, 147
Corn-cockle, 34, 191, 357, 374
Corn-spurrey, 191
Cornus, 231
Corolla, 238
Corollas : caryophyllaceous, 254 ; rosaceous, 254 ; hypocrateriform, 255 ; rotate, 255 ; tubular, 255 ; gamopetallous, 256 ; infundibuliform, 256 ; campanulate, 256 ; labiate, 257 ; personate, 258 ; calceolate, 261 ; gibbous, 262 ; globose, 262 ; urceolate, 262 ; mitræform, 262 ; papilionaceous, 263 ; ligulate, 264 ; paracorolla, 266
Corona, 266
Coryanthes, 317, 332
Corylus, 344, 369
Corymb, 234
Cotton-plant, 21, 338
Cotyledon, 115
Cowbane, 46
Cowley and the study of Nature, 1
Cowslip, 175, 229, 230, 297
Cow-tree, 38
Crab-tree, 187
Cranesbill, 373, 374
Cratægus, 155
Creeping fruits, 353
Creeping Loosestrife, 229
Cremocarps, 373
Crenate margin, 187
Cress, 116
Crithmum, 372
Crocus, 148, 209, 247
Cross-fertilisation, 321
Crowfoot, 311
Crow-silk, 48
Cruciferæ, 314, 362
Cruciform corolla, 253
Cryptogamia, 377
Cryptogams, 113, 146, 179
Cryptogramme, 379
Crystalloids, 41
Crystal formation and plant growth contrasted, 6
Crystals, 41
Cuckoo-flower, 173, 314
Cuckoo-pint, 31, 180, 231, 302, 323
Cucurbita, 251, 318
Culm, 154
Cumin, 44
Cuneate leaflet, 189
Cupressus, 166
Cupules, 369
Currant, 175, 368
Cuscuta, 101, 119
Cut-grass, 288
Cyanic flowers, 303
Cyanophyll, 204
Cycads, 55
Cyclamen, 148
Cyclosis, 396
Cylindrical leaf, 192
Cymes, 234
Cynodon, 130
Cypress, 166
Cypripedium, 336
Cypsela, 371
Cystocarp, 399
Cystoliths, 43
Cystopteris, 380

Daffodil, 266
Dahlia, 34
Daisy, 189, 229, 241, 264
Dalechampia, 316
Dandelion, 34, 36, 193, 229, 232, 264, 288, 302, 353, 371
Darwin, C., on radicles, 120 ; on composite flowers, 265 ; on bird pollination, 327 ; on *Ipomœa*, 289 ; on insects and coloured flowers, 300 ; on flower odours, 304 ; on honey-guides, 309 ; on pollen, 317 ; on *Orchis*, 330 ; on *Catasetum*, 331 ; on *Coryanthes*, 332
Datura, 357
Daucus, 125, 250
Davis, Prof. A., on cleistogamic flowers, 286
Dawson, Prof., and botany, 2
Dead-nettle, 257, 267, 279, 286
Deciduous calyx, 251
Deciduous leaves, 195
Decurrent leaf, 186
Decussate leaves, 192
Definite inflorescence, 233, 236
Dehiscence, 269
Dehiscence of anthers : longitudinal, 270 ; transverse, 270 ; porous, 270 ; valvular, 270
Dehiscent drupe, 363
Dehiscent fruits, 356
Delabechea, 151
Delesseria, 398
Delphinium, 250, 311, 360, 374
Delpino on *Plantago*, 345
Dentate margin, 197
Desmanthus, 203
Desmodium, 216
Devil's-fig, 291
Dextrorse climbers, 157
Diadelphous stamens, 247
Dianthus, 21, 233, 254
Diastase, 85
Diatomeæ, 393, 402
Diatoms, 22, 393, 402
Dichogamy, 295, 299
Dicotyledons, 118, 246, 342, 344, 351, 379
Dictamnus Fraxinella, 92
Digitalis, 248, 256, 291
Digitate leaf, 181
Dinoflagellates, 393
Diœcious flowers, 285
Dionœa muscipula, 65
Dioscorea Batatas, 147
Dipsacus, 186
Distichous leaves, 177
"Division of Labour," 22
Dock, 175, 344, 349
Dodder, 101, 119, 178
Dog-rose, 288
Dogsbane, 281
Dog-violet, 286
Dog-wood, 231
Dorsifixed anther, 269
Dorycnium, 358
Double Coco-nut, 367
Draba, 210
Dracontium, 206
Dracunculus, 308
Dragon Arum, 306
Dropwort, 126
Drosera, 54, 62
Drosophyllum lusitanicum, 65
Drupe, 367
Dutchman's Pipe, 322
Dutch Rushes, 386
Dwarf Mallow, 193

Earth-nut, 361
Earth-stars, 395
Ecballium, 352
Echeveria, 276
Ectocarpus, 400
Edelweiss, 231

Eel-grass, 341
Elaters, 386, 393
Elecampane, 34
Elder, 26, 307, 316
Elliptical leaf, 180
Ellis on American forests, 31
Elm, 223
Elodea canadensis, 29
Ebracteate flowers, 231
Elymus arenarius, 127
Emarginate, 187
Embryo, 350
Embryo-sac, 350
Enchanter's Nightshade, 241
Endocarp, 355
Endoderm, 125
Endosmose, 76
Endosperm, 116, 350
Endospore, 389
Entire leaf, 180
Entomophilæ, 335
Environment, 200
Eperua, 336
Epicalyx, 251
Epicarp, 355
Epidermis, 55, 141
Epigynous flowers, 276
Epilobium, 270, 290, 376
Epiphragm, 392
Epiphyllous buds, 172
Epiphytic Club-mosses, 387
Epispore, 384
Equisetaceæ, 378, 379
Equisetinæ, 379, 386
Equisetum, 386
Ercilla volubilis, 157
Erianthus Ravennæ, 146
Erica, 248, 262
Erodium, 322
Eryngium maritimum, 128
Erythrina, 336
Erythrophyll, 225
Eschscholtzia, 251
Essential floral organs, 238
Eucalyptus, 162
Eucalyptus, 211
Euphorbia, 33, 38, 39, 52, 80, 92, 100, 156, 210, 218, 315
Evening Primrose, 320
Evergreens, 171
Ewart, Dr. A. J., on inhibition of assimilation, 85
Exalbuminous seed, 351
Exosmose, 76
Exospore, 389
Explosive flowers, 346
Extine, 350
Extrorse anther, 269

Fagus, 175, 369
Fall of the leaf, 225
Fallow, 61
False Dittany, 92
Fasciation, 224
Fascicle, 233
Ferns, 51, 112, 174, 179, 379
Fertilisation of flowers, 239
Festuca, 219
Feverfew, 34
Fibrillæ, 16, 49
Fibro-vascular bundles, 51, 141
Fibro-vascular tissue, 55
Ficus, 43, 133, 160, 162, 166, 169, 209, 304
Fig, 30
Fig, Wild, 160
Figwort, 262
Filament, 238
Filices, 174, 378, 379
Filicinæ, 379
Filiform leaf, 190, 202
Filmy ferns, 382
Fir-cone, 178
Fission plants, 393
Fistular leaves, 209
Fixed oils, 40
Flag, 147, 190
Flax, 40
Flint, 25
Floral adhesion, 248
Floral envelopes, 238
Floral forms, 228, 249
Floral number, 246
Floral variation, 246
Floral whorls, 246
Florets, 229, 264
Florideæ, 94, 340
Flowering Rush, 22
Flowerless plants, 146, 377
Flower odours, 304
Flowers and insects, 228
Foliose Hepatics, 392
Follicle, 360
Food of plants, 57
Forget-me-not, 229, 266, 289
Forked hairs, 210
Formic acid, 220
Forms of roots, 106, 125
Foxglove, 248, 256, 291
Fragaria, 149, 257
Fraxinus, 284
Fronds, 179, 207
Fuchsia, 42, 246, 320, 336
Fucus, 400
Fungi, 55, 95, 179, 393; luminous, 95; slime, 393
Furze, 102

Galactodendron utile, 38
Galanthus, 278, 290
Galeate calyx, 250
Galium, 153, 363
Galls, 223
Gametangia, 400
Gamete, 395, 400
Gametes, 350
Gamopetalous corolla, 247, 256
Gamosepalous calyx, 247
Garden Convolvulus, 289, 301, 302
Geaster, 395
Genista, 155
Gentian, 233, 278
Gentiana, 125, 233
Geranium, 44, 275, 295, 373, 374
Germination, 115
Germ-sphere, 350
Germ-tubes, 395
Gibbous corolla, 262
Gill-by-the-Ground, 189
"Gills," 385
Gladiolus, 148
Glands, 54
Glandular hairs on calyx, 280
Gleditschia, 202
Gleichenia, 173
Globose calyx, 252
Globose corolla, 262
Glomerulus, 234
Gloxinia, 172
Glucose, 32, 39
Glumes, 232
Gluten, 40
Goat's-beard, 232, 282, 371
Goat's-thorn, 39
Goethe on evolution of floral organs, 240
Godwinia, 206
Gooseberry, 251, 368
Goose-grass, 363
Gordon-Cumming, Miss, on Sea Coco-nut, 367
Gossypium, 338
Gourds, 318, 368
Gramineæ, 115, 174, 268, 342
Grasses, 174, 184, 268, 345
Grass of Parnassus, 267
Grass-wrack, 340
Gray, Asa, on *Kalmia*, 326; on *Sarracenia*, 72
Grape, 368
Grape Vine, 262
Grapnel-plant, 364
Green Algæ, 393, 400
Ground Ivy, 189
Ground-nut oil, 41
Groundsel, 289
Ground tissue, 55, 141, 143
Guard-cells, 79
Guests of flowers, 277
Gum-arabic Plant, 361
Gum tragacanth, 39
Gymnaic acid, 35
Gymnema, 35, 38
Gymnogramme, 380
Gymnosperms, 55, 342, 344, 349, 351, 379
Gymnostomous sporange, 391
Gynandrous adhesion, 248
Gynæcium, 271

Haastias, 9
Hard-fern, 379
Hare's-ear, 186, 191
Harpagophytum, 364
Hart's-tongue, 379
Hastate leaf, 190
Haulm, 209
Hawk-moths and tubular flowers, 256
Hawthorn, 307
Hay Maid, 189
Hazel, 344, 369
Heartsease, 116
Heath, 248, 262
Hedera, 27, 132, 150, 157, 166
Helianthus, 34, 88, 147
Hellebore, 181
Helleborus, 181
Helminthia, 371
Helwingia, 174
Hemlock Spruce, 44

Hemlock Stork's-bill, 322
Hemlock Water-dropwort, 46
Henbane, 251
Henslow, Prof., on cleistogamic flowers, 288; on self-fertilising flowers, 293
Hepaticæ, 55, 81, 378, 390
Herbaceous plants, 150, 152
Herb-paris, 184, 229
Hermaphrodite flowers, 284
Hesperidium, 368
Hesperis, 304
Heterophyllous leaves, 190
Heterostylism, 297
Hevea, 37
Hibiscus, 318
Hilum, 116
Hippcastrum, 79
Hippophaë, 347
Holly, 172, 177, 195, 209, 218
Hollyhock, 244
Holocyclic stems, 153
Honesty, 252, 362
Honey, 311
Honey-flower, 317
Honey-guides, 253, 308
Honey-locust Tree, 202
Honeysuckle, 186, 255, 280, 307, 308
Hook climbers, 157
Hookeria, 94
Hooker, Sir J., on luminous fungi, 96; on "mealum-ma," 221
Hop, 21, 26, 101, 157, 161
Hop Hornbeam, 376
Horehound, 210
Horse-chestnut, 45, 169, 181, 363
Horse-tails, 379, 386
Humulus, 21, 26, 101, 157, 161
Hyacinth, 148, 303
Hyacinthus, 303
Hydrogen, 58
Hydrophilæ, 338
Hydropterideæ, 379, 384
Hymenium, 395
Hymenomycetes, 98, 395
Hymenophylleæ, 378, 382
Hyoscyamus, 251
Hypanthodium, 234
Hypericum, 244
Hyphomycetes, 393
Hypocrateriform corolla, 255
Hypogynous flowers, 275

Iberis, 363
Ilex, 172, 177, 195, 209, 218
Imbricated æstivation, 244
Impari-pinnate leaf, 180
Impatiens, 28, 288, 316, 337, 338, 352, 373
Imperfect flowers, 284
Incomplete flowers, 284
Indian Crocus, 309
Indian Cups, 72
Indiarubber, 37, 43, 169, 209
Indefinite inflorescence, 233, 237
Indehiscent fruits, 356, 364
Indusium, 379
Inflorescence, 229
Infundibuliform corolla, 256
Infusoria, 22
Innate anther, 269
Insect platforms and perches, 308
Integuments of ovule, 350
Intine, 350
Interfascicular cambium, 145
Internodes, 153
Introrse anther, 269
Inula, 34
Inulin, 34, 39
Involucre, 232
Involute vernation, 175
Ipecacuanha, 127
Ipomœa, 289, 301, 302, 318
Iris, 42, 147, 148, 190, 357
Irregular flowers, 253
Irregularity of form, 308
Irritability, 325
Isoëtes, 378, 388, 389
Ivory-nut, 118
Ivy, 27, 132, 150, 157, 166, 301, 370, 316

Jasmine, 44
Jasminum, 44
Jatropha, 33
Jerusalem Artichoke, 34, 147
Job's-tears, 370
John-go-to-bed-at-noon, 282
Johnston on *Cypselas*, 371
Juglans, 43, 285
"Jumping Beans," 353
Jumping leaf, 174
Juncus, 22
Juniper, 285
Juniperus, 285
Jurinea, 281

Kalmia, 325
Kamschatkan Lily, 347
Keel, 263
Kendall's philomath, 2
Kerner on milky juices of plants, 37; on tannin, 44; on wax coverings, 45; on temperature of opening flowers, 87; on luminous Fungi, 98; on mice and Soapwort, 125; on *Polyrhiza*, 132; on tropical orchids, 136; on *Bauhinia*, 151; on climbers, 157; on *Nardus*, 219; on *Aretia*, 255; on *Antirrhinum*, 261; on composite flowers, 265, 281; on stigmas, 274; on *Cyclamen*, 278; on floral clocks, 282; on *Argemone*, 291; on Figs, 304; on flower odours, 308; on leaf-glands in *Impatiens*, 317; on *Vallisneria*, 341; on *Dorycnium*, 358; on plants burying their fruits, 361
Khus-Khus, 44, 92
Kidney-shaped leaf, 197
Kingsley, C., on a West Indian Bladderwort, 70; on *Schnella*, 77; on Mamures, 158; on "monkey-pots," 360
Kitasato bacillus, 15
Knapp on *Apocynum*, 281
Knapweed, 241, 290
Kon-tree, 140

Labiate corolla, 257
Laciniated leaf, 208
Lactuca, 37, 218
Laminaria, 162, 400
Lamium, 257, 267, 286
Lanceolate leaf, 187
Land-turtle's Ladder, 150
Lapageria, 270, 318
Laportea, 201
Larix, 55
Larkspur, 311, 360, 374
Lateral style, 272
Latex, 52
Lathyrus, 157
Lattice-leaf Plant, 207
Lavandula, 40
Lavender, 40, 43, 46, 307
Laurel, 316
Laurus, 172
Layer of separation, 226
Leaf-bud, 169
Leaf climbers, 157
Leaf forms, 179
Leaf nectaries, 316
Lecythis, 359
Leersia, 288
Legume, 360
Leguminosæ, 215, 279, 361
Leitneria, 271
Lemons, 44, 368
Leukoplasts, 32
Leontopodium, 231
Lepidium, 116
Leptodermis, 374
Lessonia, 162, 400
Lettuce, 36, 37, 218
Liantesse, 77
Liber, 144
Lichens, 29, 55, 394
Light stimulus, 81
Lignin, 24
Ligulate corolla, 264
Ligule, 180
Ligustrum, 187, 192
Lilac, 192, 255, 290, 307
Lilium, 88, 229, 311
Lily, 148, 246, 311
Lily of the Valley, 147, 230
Lime-galls, 223
Lime-tree, 42, 54, 163, 166, 232, 244, 304
Linaria, 258, 361
Linear leaf, 187
Lindley, Dr., on Geranium fruits, 373; on studying botany, 2
Linseed-oil, 40
Linum, 40, 102
Lip-cells, 380
Liriodendron, 169, 197
Listera, 320, 328
Liverworts, 55, 81, 390, 392
Lobelia, 300, 336
Loculi, 357
Loculicidal dehiscence, 357
Lodoicea, 367
Lomaria, 379
Lomentum, 361
London Pride, 189

Lonicera, 186, 255, 280
Loranthaceæ, 161
Loranthus, 122
Lotus, 279
Lousewort, 279
Lucerne, 189, 361
Luminosity of plants, 87
Luminous Mosses, 93
Lum-tree, 140
Lunaria, 252, 362
Lupins, 214
Lychnis, 254, 357, 374
Lycoperdon, 395
Lycopodiaceæ, 378, 379, 387
Lycopodinæ, 379, 387
Lycopodium, 377, 387
Lyme-grass, 127
Lyrate leaf, 191
Lysimachia, 229
Lythrum, 298

McAlpine, Prof., on fertilisation of *Algæ*, 399
Macrocystis, 162, 400
Madder-plant, 79
Magnolia, 295, 307, 360
Maiden Pink, 254
Maize, 116
Malacophilæ, 335
Malcolmia, 21
Malic acid, 35
Mallow, 118, 251, 373
Malva, 118, 193, 251, 295, 373
Mamillaria, 26
Mamures, 158
Mandioc-root, 39
Mandragora, 126
Mandrake, 126
Mangrove, 138
Manihot, 39
Manubrium, 396
Maple, 138, 202, 372
Marattiaceæ, 383
Marcgravia, 159, 337
Marchantia, 81
Marchantiaceæ, 392
Marigold, 88 ; African, 88
Maritime Pine, 45
Marjoram, 43
Marram, 127
Marrubium, 210
Marsh-calla, 306, 335
Marsh plants, food of, 62
Marsilea, 207, 385
Martagon Lily, 88
Martynia, 363
Marvel of Peru, 210
Masterwort, 184
Mat-grass, 219
Mathiola, 362
Matricaria Parthenium, 34
Matweed, 212
May-tree, 155
Meadow-cranesbill, 295
Meadow-crocus, 209
Meadow-rue, 180
Meadow-saffron, 357
Medicago, 189, 361
Medick, 189
Medulla, 143
Medullary rays, 143
Medullary sheath, 51, 142
Megasporange, 384
Megaspore, 384
Melastoma, 270
Melianthus, 317
Melocactus, 26
Melon, 251
Mentha, 40
Menyanthes, 30
Mericarps, 372
Mericyclic stems, 153
Meristem, 54
Mesocarp, 355
Mesophyll, 378
Metabolism, 39
Metrosideros, 160
Micrococci, 14
Micropyle, 116, 350
Microsporange, 384
Microspore, 384
Midrib, 180
Mignonette, 248, 304
Mimosa, 214, 215, 318
Mimulus, 318
Mint, 40
Mirabilis, 210, 283
Mistletoe, 27, 318, 368
Mitræform corolla, 262
Molucella, 250
Monachanthus, 330
Monadelphous stamens, 247
Monarda, 301
Moneywort, 229
Moniliform hairs, 210
Moniliform pod, 361
Monkey-ladder, 152
Monkey-nut, 41
"Monkey-pots," 359
Monkshood, 125, 181, 250
Monocotyledons, 51, 118, 146, 246, 342, 344, 351, 379
Monœcious flowers, 285
Monosymmetrical flowers, 253
Monstera, 208
"Monstrous" flowers, 241
Moonwort, 383
Mora, 160
Mora-tree, 160, 162
Morus, 356
Moss "flower," 391
Mosses, 55, 86, 110, 179, 379, 390 ; luminous, 93
Motile plants, 10, 11
Mountain-ash, 307
Mucor, 394
Mucronate leaf, 189
Mulberry, 356
Mullein, 210
Müller, H., on Foxglove, 297; on *Lamium*, 258 ; on Snowdrop, 278 ; on *Aspidistra*, 297 ; on *Lythrum*, 298 ; on *Amorphophallus*, 301 ; on *Arum*, 306 ; on *Atragene*, 314 ; on *Cardamine*, 314 ; on *Listera*, 320
Multicellular plants, 12
Musa, 46
Musci, 51, 86, 110, 390
Mushrooms, 107, 108, 393, 395
Musk, 318
Mustard, 116, 191
Myanthus, 330
Mycele, 393
Mycelia, 95, 108
Myosotis, 229, 288, 289, 303
Myristica, 376
Myxogasters, 98
Myxomycetes, 393, 402

Narcissus, 266
Nardus, 219
Nasturtium, 157, 311, 373
Nectar, 310
Needle-shaped leaf, 195
Negro's-head Palm, 118
Nelumbium, 194
Nepenthes, 71, 73, 200
Nerine Lily, 318
Nettles, 43, 220, 346
Net-veined leaf, 180
Neuropeltis, 232
Neuter flowers, 285
New Abbey Plane, 62
New Holland Pitcher-plant, 72
Nicandra, 210
Night-flowering Stock, 304
Nitella, 15, 396
Nitrogen, 59
Nodes, 153
Non-nitrogenous compounds, 40
Norfolk, or four-course rotation, 60
Nucellus, 350
Nucleoplasm, 16
Nucleus, 16
Nut, 369
Nutmeg-tree, 376
Nutrition, 57
Nymphæa, 243, 245, 271, 318, 357
Nymphæaceæ, 118

Oak, 23, 44, 120, 164, 181, 285, 369
Oak-galls, 223
Oak in Normandy, 164 ; Salcey, 164 ; Winfarthing, 164 ; Greendale, 164 ; Cowthorpe, 166
Oat, 34, 233
Obcordate leaflet, 187
Oblique leaf, 194
Oblong leaflet, 189
Obovate leaf, 187
Obtuse apex, 198
Octastichous leaves, 177
Œnanthe crocata, 46
Œnothera, 91, 320
Oils : fixed, 40 ; olive, 40 ; palm, 40 ; linseed, 40 ; rape or colza, 40 ; castor, 41 ; volatile, 43 ; aromatic, 43 ; clove, 44 ; lemon, 44 ; turpentine, 44 ;
Olea, 40, 166
Olive, 40, 166
Onion, 42, 148, 209
Ononis, 155, 156, 218
Oogones, 396
Oogonium, 402
Oomycetes, 394
Oophyte, 110, 390
Oosperm, 350, 385
Oosphere, 350, 380, 385, 397
Oospore, 402

Opercule, 391
Ophioglossaceæ, 383
Ophioglossum, 383, 384
Opium, 37
Opposite leaves, 192
Opuntia, 26, 27, 219
Orange, 368
Orbicular leaf, 193
Orchids, 9, 26, 30, 33, 132, 308, 320, 323, 328
Orchis, 328
Ornithophilæ, 335
Orobanche, 101, 102
Orthotropous ovule, 349
Oryza, 34
Osier, 198
Osmunda, 382
Osmundaceæ, 382
Ostrya, 376
Ouvirandra, 207
Ovarian nectaries, 316
Ovary, 238, 275, 351
Ovate leaf, 187
Ovule, 238, 357
Ovuliferous scales, 376
Ovum, 350
Oxalate of lime, 42
Oxalis, 43, 120, 150, 187, 214, 215, 288, 352
Oxidation, 86
Oxlip, 230, 297

Pales, 232
Palisade-parenchyme, 378
Palm, 150
Palmately veined, 181
Palmatifid, 181
Palmatipartite, 181
Palmatisect, 181
Palm-oil, 40
Pandanus, 44, 130
Panicle, 233, 234
Panicum, 159
Pansy, 253
Pao-Barringudos, 151
Papaver, 37, 41, 116, 191, 251, 310, 357
Papilionaceous corolla, 263
Papilionaceous flowers, 315
Pappus, 266
Paracorolla, 266
Parallel-veined, 180
Paraphyse, 380
Parasites, 393
Parasitical plants, 101
Parenchyma, 53
Parietaria, 346
Pari-pinnate, 180
Paris, 184, 229
Parnassia, 267
Parsley, 301
Parsley-fern, 379
Pasque-flower, 315
Passiflora, 267, 318
Passion-flower, 267, 318
Path-finders, 253, 308
Pavia, 363
Paxiuba, 130
Pea, 150, 247, 263, 315, 323, 349, 361
Peach-flower, 241
Pear, 251, 278
Pearlwort, 193
Pedicel, 230
Pedicellate flowers, 229
Pedicularis, 279
Peduncle, 230
Pelargonium, 91, 126, 295
Peloria, 259
Peltate leaf, 194
Pendulous flowers, 278, 344
Penicillium, 19
Peony, 288, 360
Pepo, 368
Pepper, 351
Peppermint, 43
Perennial plants, 152
Perfoliate leaf, 186
Perianth, 242
Pericarp, 355, 397
Perichæte, 391
Peridineæ, 393, 402
Peridium, 395
Perigone, 391
Perigynous flowers, 276
Perisperm, 118, 357
Peristome, 392
Peronospora, 394, 395
Persistent calyx, 251
Personate corolla, 258
Petaloid bracts, 231
Petaloid sepals, 242
Petals, 238
Petiole, 180
Peucedanum, 184
Phæophyceæ, 393, 399
Phallus, 42
Phanerogamic fruit, 355
Phanerogams, 113, 178
Phascaceæ, 392
Pheasant's eye, 302
Phloëm, 144, 377
Phlox, 255, 257
Photosynthesis, 83
Phragmites, 209
Phrynium, 361
Phyco-erythrin, 94, 398
Phyllanthus, 155
Phyllode, 201
Phylloglossum, 378
Phyllonoma, 174, 198
Phyllotaxy, 175
Physalis, 251, 303
Physianthus, 327
Phytelephas, 118
Pickerel Weed, 203
Pilea, 346
Pillworts, 146, 384
Pilularia, 146, 378, 384
Pimpernel, 192, 359
Pine, 376
Pineapple, 356
Pine, red, 44
Pinguicula, 68
Pink, 21, 233, 307
Pinnæ, 201
Pinnate leaf, 180
Pinnatifid leaf, 191
Pinnatisect leaf, 191
Pinnules, 173
Pinus, 44, 45, 318, 342, 376
Piperaceæ, 351
Pistil, 238, 248, 271
Pistillate flowers, 285
Pisum, 150, 323
Pitcher-plants, 71, 75
Pitted cells, 25
Plane-tree, 163
Planogametes, 400, 402
Plantago, 295, 345
Plantain, 345
Plant marriages, 321
Platanus, 163
Plicate vernation, 175
Plum, 175, 367
Plumbago, 280
Plume-thistle, 186, 353
Plumule, 115
Pod, 360
Poinsettia, 231
Pokutukama-tree, 160
Polar-plant, 80
Pollen, 238, 288, 317
Pollen-grains, 14, 47, 288
Pollinium, 320, 328
Polyadelphous stamens, 247
Polycotyledons, 119
Polygamous flowers, 285
Polygonatum, 147
Polygonum, 44
Polypetalous corolla, 247
Polypodiaceæ, 380
Polyporus, 395
Polyrhiza, 132
Polysepalous calyx, 247
Polysiphonia, 399
Polystelic roots, 125
Polytrichum, 392
Pome, 356
Pond-weed, 347
Pontederia, 203
Poor Man's Weather-glass, 192
Poplar, 45, 154, 285, 376
Poppy, 37, 41, 91, 116, 191, 257, 310, 357
Poppy-oil, 41
Populus, 45, 154, 216, 285, 376
Porous capsules, 357
Portuguese Sundew, 65
Potamogetons, 203, 347
Potato, 33, 34, 147, 219, 244, 270
Potentilla, 187
Prefloration, 244
Prefoliation, 174
Prickles, 218
Prickly Pear, 27, 219
Primary root, 114
Primrose, 247, 252, 297, 230
Primula, 54, 175, 229, 230, 252, 255, 266, 297
Privet, 186, 192
Proembryo, 397
Prosenchyma, 53
Proteaceæ, 360
Proteids, 40
Proteolytic enzymes, 85
Proterandrous flowers, 295
Proterogynous flowers, 295
Prothallium, 379
Prothallus, 113
Protococcoideæ, 400
Protonema, 110
Protoneme, 382, 390
Protophytes, 113

Protoplasm, 13, 16, 57
Protoplast, 5, 20
Prunus, 155, 156, 175, 218, 229, 316
Psamma, 127, 211
Pseudocarps, 355
Pseudo-syncarp, 356
Psilotum, 378
Pteris, 379
Pternandra, 251
Puff-balls, 395
Pulvinus, 216
Punch and Judy Orchid, 9
Purple Loosestrife, 298
Pyrus, 187, 251
Pyxis, 359

Quadrate, 184
Quercus, 21, 25, 44, 285, 369
Quillworts, 379, 389
Quinate, 184
Quiscalis, 374

Raceme, 234
Rachis, 180, 230, 383
Radical leaf, 193
Radicle, 115
Rafflesia, 101, 229, 306
Ragwort, 181
Rangoon Creeper, 374
Ranunculus, 186, 190, 202, 233, 251, 254, 284, 291, 311, 369
Raoulias, 9
Rape, 41
Rape-oil, 41
Raspberry, 150, 356
Rata, 160
Ravenna-grass, 146
Rayed floret, 264
Receptacle, 238, 264, 356
Red Algæ, 393
Red Seaweeds, 94, 340
Red Whortleberry, 198
Reed, 209
Reed-mace, 209
Regular flowers, 252
Rejuvenescence, 48
Reniform leaf, 187
Respiration, 85
Replum, 362
Reproduction, 57
Reseda, 248
Resin, 44
Rest-harrow, 155, 218
Resting-spores, 395
Retuse apex, 198
Revolute vernation, 175
Rheum, 125
Rhizocarpeæ, 378
Rhizoids, 81
Rhizomes, 147, 230
Rhizomorpha, 95
Rhizopods, 22
Rhodea, 336
Rhodophyceæ, 393, 398
Rhubarb, 125
Ribes, 175, 251
Rice, 34
Riccia, 393
Ricinus, 41
Rise of temperature in opening flowers, 87
Rochea, 210
Rodway on *Loranthaceæ*, 160
Roots, 106, 120, 125, 126, 127, 130; polystelic, 125; tap, 125; fibrous, 126; tuberous, 126; moniliform, 126; nodulose, 126; annulated, 126; testicular, 127; fascicular, 127; fusiform, 125; napiform, 125; adventitious, 130; aerial, 130
Root-buds, 172
Root-cap, 124
Root-climbers, 157
Root-sheath, 125
Rosa, 40, 91, 218, 288
Rosaceous corolla, 254
Rose, 91, 218, 241, 244, 251, 276, 307
Rosemary, 43
"Rose of Jericho," 362
Rostellum, 320
Rotate corolla, 255
Rotation, 18
Rotation of crops, 60
Rubia, 79
Rubus, 150, 157, 356
Rue, 307
Rumex, 175, 190, 344
Runcinate leaf, 193
Ruppia, 340
Ruscus, 154
Rush, 22, 154, 345
Ruskin on *Soldanella*, 86; on Mosses, 111; on Grasses, 184
Rye, 345

Saccate calyx, 252
Saccharomyces, 86
Saccharum, 36
Saccolobium guttatum, 26
Sacred Lotus, 194
Sage, 324, 336
Sagina, 193
Sagittaria, 190, 285
Sagittate leaf, 190
Sago Palm, 207
Salix, 153, 169, 198, 285, 376
Salver-shaped corolla, 255
Salvia, 26, 324, 337
Salvinia, 378
Samara, 372
Sambucus, 26
Samolus, 187
Samphire, 372
Sanderson, Dr. B., on *Dionæa*, 67
Sap, 34
Saprolegnia, 394
Saprophytes, 393
Sarcocarp, 355
Sarcode, 16 (*note*)
Sarracenia, 71, 200
Saxifraga, 189, 310
Saxifrage, 195, 310
Scalariform tracheides, 377
Scale-fern, 171
Scale-leaves, 169
Scale-mosses, 390, 392
Scapes, 63, 230
Schistostega, 94
Schizocarps, 356, 372
Schizomycetes, 14
Schizophyta, 393, 402
Schnella excisa, 77
Scilla, 247
Sclerenchyma, 24, 53
Scolopendrium, 174, 379
Scorpion-grass, 288, 303
Scorpiurus, 361
Scots Pine, 318, 342
Screw-pine, 44, 130
Scrophularia, 262, 295
Sea-buckthorn, 347
Sea-coco-nut, 367
Sea-holly, 128
Sea-reed, 211
Sea-ruppia, 340
Sea-sedge, 127
Sea-wrack, 162
Sebastiania, 354
Secale, 345
Secondary deposit, 23
Sedges, 345
Seed, 350
Seed dispersion, 351
Selaginella, 377, 379, 388
Selaginellaceæ, 378, 379, 387, 388
Selective power of roots, 59
Senecio, 181, 289
Sensitive plants, 10
Sepals, 238, 242
Septenate, 184
Septicidal dehiscence, 357
Septifragal dehiscence, 358
Septum, 388
Sequoia, 161
Serrate margin, 180
Serratula, 281
Sessile anther, 269
Sessile flowers, 229
Sessile leaf, 185
Sessile style, 272
Shaddock, 368
Sheath, 179
Sheep's-sorrel, 190, 344
Shepherd's Purse, 294, 349, 363
Shrubs, 152
Side-saddle-flowers, 72
Sieve-plates, 51
Sieve-tubes, 51, 377
Silene, 254, 281
Silica, 25
Silicula, 362
Siliqua, 362
Silk-cotton-tree, 162
Silphium, 80, 211
"Silver grain," 143
Simple hairs, 210
Simple pistils, 248
Simple umbel, 234
Sinapis, 191
Sinistrorse climbers, 157
Sinuate leaf, 181
"Sleep" of plants, 212
Slime Fungi, 393
Sling-fruits, 359, 373
Smilax, 157
Snapdragon, 233, 239, 244, 259
Snowberry, 21
Snowdrop, 278, 290

Solanum, 33, 34, 147, 158, 195, 218, 255, 270
Soldanella, 86, 290
Solitary flowers, 229
Solomon's Seal, 147
Sonchus, 371
Sorrel, Common, 43 ; Wood, 43
Sorus, 113, 379, 384
Sow-thistle, 371
Spadix, 232, 234
Spathe, 232
Spathulate leaf, 189
Spearmint, 43
Speedwell, 316
Spergula, 191
Spermatium, 399
Spermatozoids, 400
Sphærella pluvialis, 10, 17, 47
Sphagnum, 26
Spiderwort, 18, 210
Spikelet, 233
Spikes, 234
Spindle-shaped cells, 25
Spines, 155
Spiræa, 126
Spiral æstivation, 244
Spiral cells, 26
Spirochæte, 15 (*note*)
Spontaneous generation an assumption, 5
Sporange, 379
Sporangia, 111, 112
Spore, 377
Sporocarps, 384
Sporogenous tissue, 379
Sporophore, 393
Sporophylls, 386, 388
Sporophyte, 385
Sprengel on colours of flowers, 301
Sprossglied, 153
Spruce, 44
Spur, 250
Spurge, 39, 218, 315
Squirting Cucumber, 352
Stamens, 238
Staminate flowers, 285
Staminodes, 314
Standard, 263
Stanhopea, 333
Starch, 31, 39
Star-thistle, 185
Stele, 125
Stellate cells, 21
Stellate hairs, 210
Stems, 141
Stengelglied, 153
Sterigmas, 382
Stigma, 238, 272, 391
Stinging hairs, 220, 223
Stipule, 180
St. John's Wort, 244
Stock, 362
Stomata, 79, 81, ; water, 80
Stomates, 378
Stone-fruit, 367
Stoneworts, 393, 396
Strawberry, 149, 157, 251, 356
Strelitzia, 337
Strobile, 234, 344
Style, 238, 272
Sub-drupaceous capsule, 363
Suberin, 24
Sub-rotund leaf, 193
Subulate leaves, 193
Succory, 191
Succulent capsule, 363
Sugar Cane, 36
Sugar : cane, 36 ; grape, 36, 39
Sugar Maple, 36
Sumach, 301
Sundew, 54, 62
Sunflower, 34, 88
Swarm-spores, 400, 402
Sweet Briar, 40
Sweet Buckeye, 363
Sweet Chestnut, 285
Sweet Pea, 157
Sword-shaped leaf, 190
Sycamore, 192
Symbiosis, 394
Symphytum, 316
Syncarp, 356
Syncarpous pistils, 248
Synergidæ, 350
Syngenesious stamens, 247
Syringa, 192, 255, 290

Tabasheer, 43
Tacsonia, 337
Tagetes, 88
Tangs, 399
Tannin, 44
Tapioca-plant, 33; S. African, 52
Tap-roots, 125
Taraxacum, 34, 36, 193, 229, 232, 264, 353
Tassel-grass, 340
Taxus, 55, 166, 349, 376
Taylor, Dr. J. E., on plant laboratories, 39 ; on "Monstrous" flowers, 241
Teasel, 186
Telegraph-plant, 216
Tendrils, 157
Terebinth, 45
Terminal buds, 172
Terminal flowers, 229
Terminal style, 272
Ternate, 184
Testa, 370
Tetraspores, 398
Thalamus, 356
Thalictrum, 180
Thallasiophyllum, 208
Thalloid Hepatics, 392
Thallophyta, 393
Thistle, 219, 371
Thorn-apple, 357
Thorns, 155
Thorow-wax, 186, 191, 278
Thyme, 43, 102, 307
Thymus, 102
Thyrsus, 234
Tilia, 42, 202, 232, 244
Tillandsia, 353
Tissues, 52, 141
Ti-tree, 160
Toadflax, 258, 279
Tobacco, 46
Tomentum, 210
Toothed capsules, 357
Touch-me-not-Balsam, 28, 352
Tower Mustard, 190
Tracheides, 55
Tradescantia, 18, 210
Tragopogon, 232, 282, 371
Trail, Prof., on *Cordyceps*, 105 ; on nectar, 310
Transfusion tissue, 55
Transpiration, 81
Trapa, 203
Travellers' Joy, 157
Treat, Mrs., on American Sundew, 64 ; on Bladderwort, 69
Tree-fern, 160
Trefoil, 181
Trees, 152
Trentepohlia, 402
Triadelphous stamens, 247
Trichogyne, 399
Trifolium, 102, 181, 279, 361
Triglochin, 347
Trigonia, 374
Trimorphic flowers, 298
Tripinnate, 180
Tristichous leaves, 177
Triternate, 184
Triticum, 126, 370
Tropæolum, 87, 157, 194, 214, 250, 311, 373
Truncate leaf, 197
Trumpet-flower, 373
Trumpet-leaves, 72
Tubers, 147
Tubular calyx, 252
Tubular corolla, 255
Tufted hairs, 210
Tulip-tree, 169, 197
Tumboa, 163
Turnip, 125
Turpentine, 44
Turritis, 190
Tussilago, 372
Twayblade, 320, 328
Typha, 209, 342

Ulex, 102
Ulmus, 223
Umbel, 234
Umbelliferæ, 295
Unicellular plants, 12
Upas-tree 38
Urceolate corolla, 262
Urceolate receptacle, 250
Urchin-crowfoot, 369
Uredineæ, 395
Urtica, 220, 346
Urticaceæ, 43
Utricularia, 69

Vaccinium, 198, 262, 270
Vacuoles, 35
Vagine, 391
Valerian, 262, 307
Valeriana, 262
Vallisneria, 19, 28, 341
Valvular dehiscence, 358
Variation, 200
Vascular bundles, 378
Vascular Cryptogams, 377, 379
Vascular cylinder, 125
Vaucheria, 15

"Vegetable Caterpillar," 105
"Vegetable Ivory," 118
"Vegetable Stones," 43
Vegetation and man, 4
Venus' Fly-trap, 65
Verbascum, 210
Verbena, 91, 269
Vernal-grass, 185
Vernation, 174, 244
Veroniea, 316
Versatile anther, 268
Vertical leaves, 211
Verticillaster, 234
Verticillate leaves, 192
Vervain, 269
Vessels, 49; spiral, 50, 144; annular, 50; reticulated, 50; pitted, 50, 144; scalariform, 51; utricular, 52; laticiferous, 52
Vetch, 180
Vexillum, 264
Vicia, 22, 150, 180, 316, 361
Victoria, 204
Vine, 157
Vine-galls, 224
Viola, 116, 175, 187, 248, 253, 286, 307, 312, 361
Violet, 175, 187, 248, 307, 312, 361
Virginia Creeper, 157, 307
Virginian Stock, 21
Viscum, 27, 318
Vitis, 104, 157, 262
Volatile oils, 43
Volvox, 10, 400
Vorticella, 10, 12

Wake-robin, 31, 180, 231
Wallaba-tree, 336
Wallace, Dr. A. R., on American Cow-tree, 38; on *Paxiuba*, 132; on Brazilian Balsam-tree, 133
Wallflower, 233, 307, 362
Wall-pellitory, 346
Walnut-tree, 43, 285, 363
Ward, Dr. N., on forests as centres of fertility, 82
Water-caltrops, 203
Water-crowfoot, 190, 202, 292
Water-ferns, 379, 384
Water-lily, 118, 203, 243, 245, 271, 318, 351
Water-pimpernel, 187
Water-smartweed, 44
Water-stomata, 80
Water-thyme, 29
Waterton on the Mora-tree, 160
Wax, 44, 45
"Weeping" of Grape-vines, 51
Wellingtonia, 161
Welwitschia, 163
Wheat, 126, 370
Wheel-shaped corolla, 255
White Willow, 198
Whitlow-grass, 210
Whorls, 192
Whortleberry, 198, 262, 270
Willow, 153, 169, 198, 285, 304, 376
Willow-herb, 270, 290, 376
"Wind Witches," 355
Winged stem, 186
Wings, 263
Winter Cherry, 251, 252, 303
Wistaria, 242, 318
Wood-anemone, 232
Woodruff, 153
Wood-sorrel, 150, 187, 288, 352
Woody Nightshade, 195, 219, 255
Woody trees, 152
Wracks, 399

Xanthic flowers, 303
Xanthium, 364
Xanthophyll, 225
Xylem, 55, 144, 377

Yam, 147
Yeast, 86
Yellow Vetchling, 157
Yellow-wort, 186
Yew, 166, 349, 376
Yucca, 333

Zea, 116
Zinnia, 302
Zoöphilæ, 338
Zoospores, 12, 394
Zostera, 340
Zygnema, 48
Zygomorphic flowers, 532
Zygomycetes, 394, 395
Zygosperm, 395
Zygospore, 402
Zygotes, 400

ERRATA

Plate III. "Meadowsweet (*Spiræa Ulmaria*)" should read "Willow-leaved Spiræa (*Spiræa salicifolia*)."
,, V. "*Cephalotus*" should read "*Sarracenia*."
Page 64, lines 4 and 19, "Mrs. Trent" should read "Mrs. Treat."
,, 70, ,, 29 and 33, ,, ,, ,, ,, ,, ,,
,, 70, line 34, "*Utricularis*" ,, ,, "*Utricularia*."
,, 71, ,, 5, "rot" ,, ,, "root."
,, 72, ,, 12, "Regina" ,, ,, "Regia."
,, 214, Figs. 269 and 270, "portion" ,, ,, "position" in each case.
,, 244, line 37, "*Lilia*" ,, ,, "*Tilia*."
,, 254, ,, 37, "*parcellus*" ,, ,, "*porcellus*."
,, 258, Fig. 363, "*stellaterum*" ,, ,, "*stellatarum*."
,, 261, ,, 372, "Aquilegia" ,, ,, "Delphinium."
,, 290, ,, 456, "corona" ,, ,, "corolla."
,, 301, line 27, "*Monarda didyma*" should be deleted, as this is the name of a plant ("Oswego-tea") instead of an insect.
,, 301, ,, 42, "*Amorphallus*" should read "*Amorphophallus*."
,, 303, Fig. 470, ,, ,, ,, ,,
,, 358, ,, 569, "seed" ,, ,, "capsule."

591—

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